Studio di dispersione termica - Data Center Campus Settimo Milanese – Heat Island Study

CFD study - Short summary

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Il presente documento costituisce una sintesi del rapporto tecnico completo relativo allo studio CFD (Computational Fluid Dynamics) relativo alla valutazione del'effeto isola di calore urbana relativo all'operatività del campus data center di Settimo Milanese, condotto dalla società EOLIOS su incarico di ERM Italia. L'obiettivo è riassumere le principali conclusioni e i risultati più rilevanti; qualora il lettore necessiti di ulteriori dettagli o di informazioni sulle ipotesi di input, è invitato a consultare la versione integrale dello studio.

Lo studio CFD condotto sui diversi scenari mette in evidenza il comportamento complessivo delle emissioni termiche generate dai chiller e dai gruppi elettrogeni in condizioni meteorologiche estive con temperature elevate, quando l'effetto isola di calore può determinare un contributo rilevante.

Per la definizione delle condizioni climatiche di baseline si è fatto riferimento ai dati della stazione meteorologica di Milano Linate, utilizzando i dataset elaborati secondo gli standard ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers). ASHRAE rappresenta un riferimento internazionale per la definizione dei dati climatici di progetto, basati su serie storiche di lungo periodo e su analisi statistiche che garantiscono condizioni rappresentative e conservative per la progettazione degli impianti HVAC.

L'utilizzo della stazione di Milano Linate è stato ritenuto appropriato in quanto rappresenta il punto di misura qualificato più vicino al sito ed è caratterizzato da una base dati consolidata e riconosciuta a livello internazionale. I dati ASHRAE, derivati da medie climatiche pluriennali (circa 25 anni) e da analisi degli estremi su periodi estesi (fino a 50 anni), consentono infatti di definire condizioni termiche e anemometriche affidabili e coerenti con gli scenari di progetto.

Per questo studio sono state adottate condizioni meteorologiche di baseline rappresentative di uno scenario meteorologico di stress estivo, corrispondenti alla temperatura massima media annuale (35,7°C) e alla velocità media mensile del vento più elevata registrata nel corso dell'anno (pari a 2,0 m/s), con direzione prevalente da est.

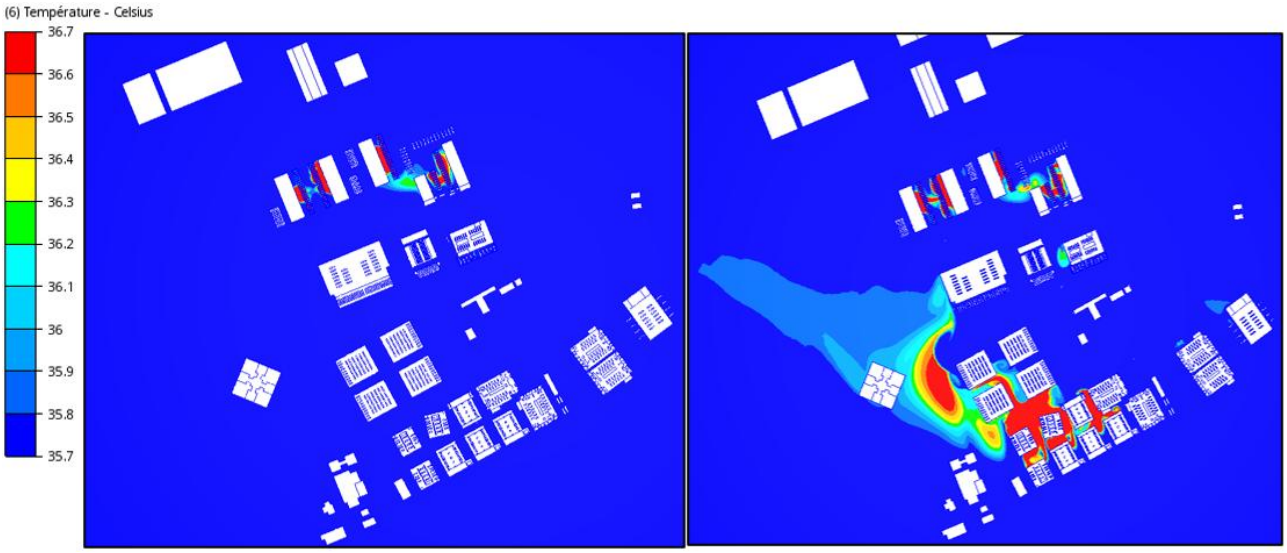
Gli scenari impiantistici simulati e dei quali si sono valutati gli effetti sono i seguenti:

- **Scenario iniziale**, che non considera le installazioni del data center, non si osservano incrementi di temperatura e le variazioni di pressione rimangono molto contenute, senza influenzare in modo significativo i flussi d'aria.
- **Scenario Equinix**: l'analisi dello scenario che include esclusivamente il campus Equinix mostra che i pennacchi termici prodotti dalle apparecchiature rimangono per lo più confinati all'interno del sito e si innalzano rapidamente grazie all'effetto combinato dei flussi di scarico verticali e della spinta termica. Gli impatti a livello del suolo e sugli edifici vicini risultano molto limitati, con incrementi di temperatura inferiori a 0,1°C al di fuori dell'immediata vicinanza dei chiller. Le aree con temperature più elevate restano localizzate all'interno del campus e non generano fenomeni significativi di ricircolazione.
- **Scenario di Campus cumulato**: lo scenario che include l'intero campus dei data center di Settimo Milanese (Equinix, Vantage, Microsoft e Data4) evidenzia interazioni aerodinamiche più pronunciate, legate all'elevata densità di sistemi di aspirazione e di edifici. Si forma infatti una significativa zona di bassa pressione a valle delle installazioni, che favorisce localmente il richiamo verso il suolo di una parte delle masse d'aria calda presenti in quota. Questo fenomeno comporta incrementi di temperatura localizzati fino a circa +1°C su una distanza di circa 75 m a valle del campus, nonché aumenti più contenuti, dell'ordine di +0,1°C, fino a circa 500 m sottovento. Tali effetti rimangono

comunque confinati in aree limitate, situate principalmente a valle del campus Data4, e non mettono in discussione il comportamento complessivamente ascendente dei pennacchi termici.

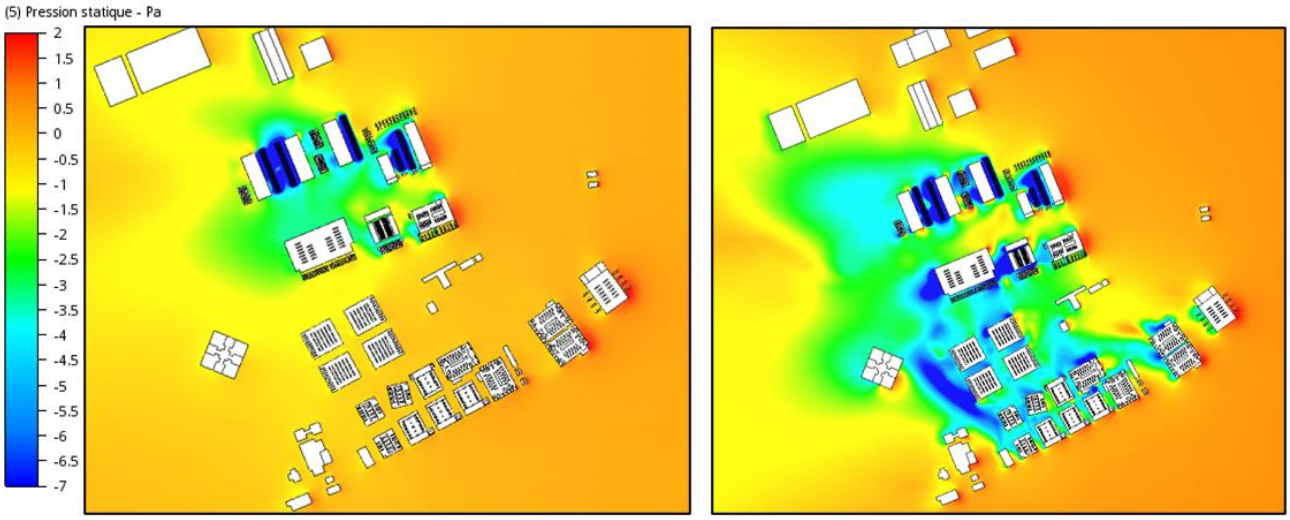
Di seguito sono riportate le mappe di temperatura a 1 m dal suolo relative, rispettivamente, allo scenario con il solo campus Equinix e a quello con l'intero campus di Settimo Milanese.

FIGURA -1: PIANI DI TEMPERATURA A 1 M - SCENARIO EQUINIX (SINISTRA) E SCENARIO DI CAMPUS COMPLETO (DESTRA)



Inoltre, l'incremento della depressione a 1,5 m, causato dall'elevata portata di aspirazione dei chiller e tale da favorire il rientro delle masse d'aria calda nella parte inferiore dell'edificio, è illustrato nei diagrammi di pressione riportati di seguito. Si osserva che la pressione risulta particolarmente più bassa nelle aree a valle degli edifici per effetto del vento. Si evidenzia inoltre che l'aumento della depressione, quando vengono considerati tutti e quattro i campus, favorisce in misura limitata anche la discesa delle masse d'aria nella parte inferiore del campus Equinix.

FIGURA -2: PIANO DI PRESSIONE A 1,5 M - SOLO EQUINIX (SINISTRA) E TUTTI E QUATTRO I CAMPUS (DESTRA)



Le isosuperfici di temperatura e le linee di flusso confermano che la dinamica dominante delle emissioni termiche consiste in una rapida risalita in quota delle masse d'aria riscaldata, seguita da una progressiva dissipazione alle quote più elevate. I fenomeni di ricircolazione osservati a

livello del suolo restano localizzati e sono direttamente collegati alle zone di forte bassa pressione indotte dalla concentrazione dei sistemi di aspirazione. Le isosuperfici e le linee di flusso riportate di seguito illustrano questa tendenza ascendente delle masse d'aria calda in uscita dai chiller.

FIGURA-3: ISOSUPERFICIE DI TEMPERATURA DI +0,5°C - SOLO EQUINIX (SOPRA) E QUATTRO CAMPUS (SOTTO)

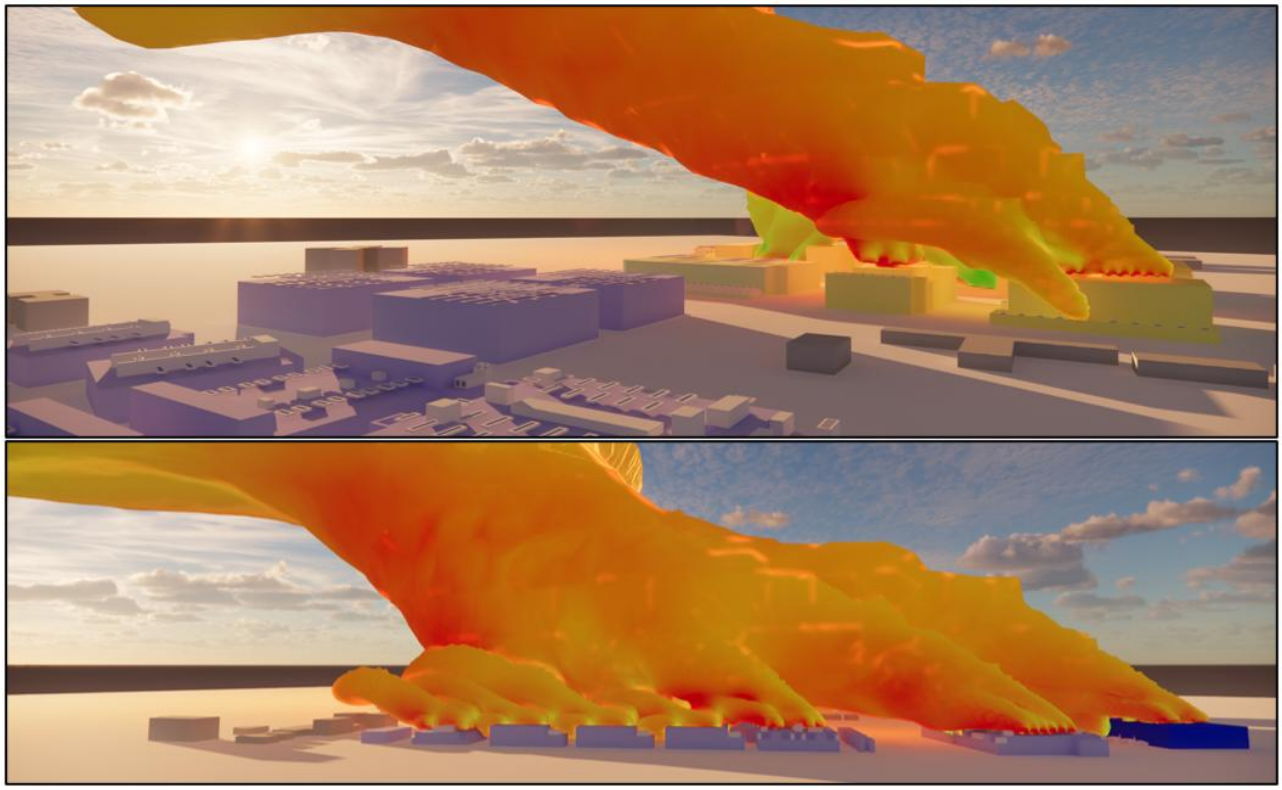
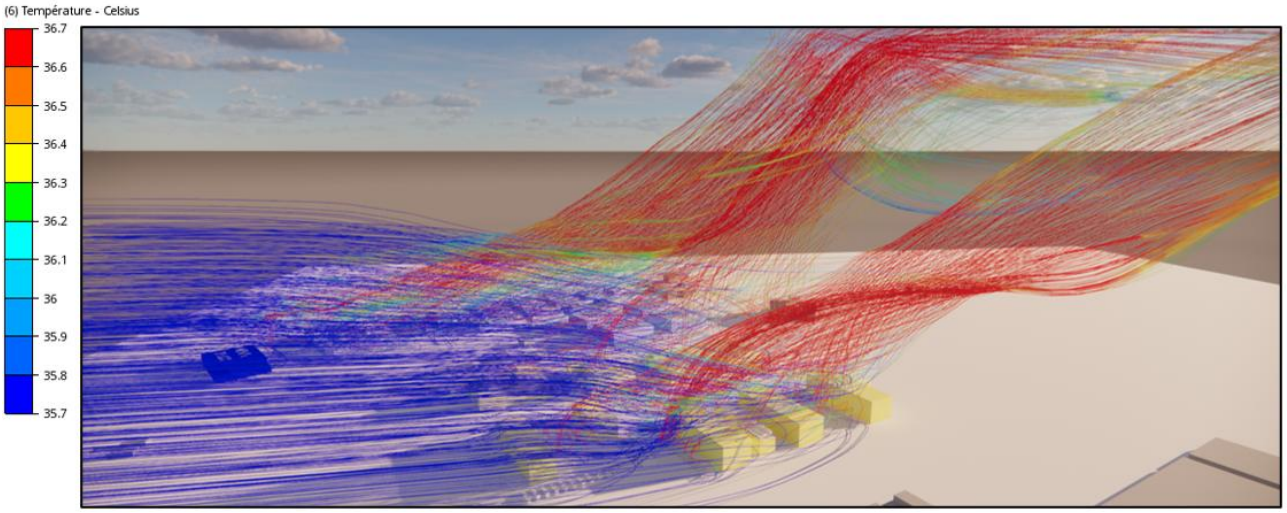


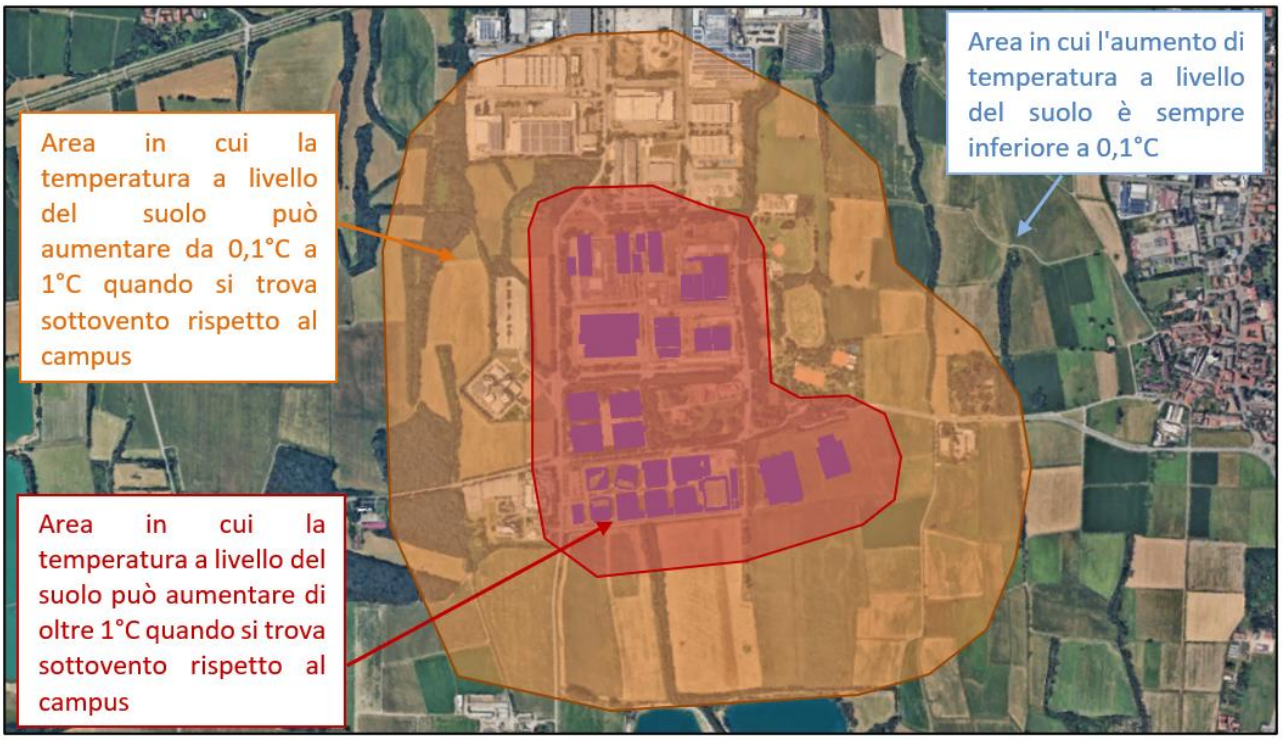
FIGURA-4: LINEE DI FLUSSO COLORATE PER TEMPERATURA – SCENARIO 4 CAMPUS



Infine, la generalizzazione dei risultati a tutte le direzioni del vento consente di individuare le potenziali aree di incremento locale della temperatura attorno ai campus, per diversi livelli di impatto termico. Questo approccio fornisce una visione d'insieme delle aree sensibili che potrebbero essere interessate da effetti di riscaldamento locale in funzione della direzione del vento, come illustrato di seguito. Gli aumenti di temperatura non si manifestano simultaneamente sull'intera area racchiusa dalle isoterme: le emissioni di calore vengono

trasportate dal vento e interessano principalmente l'area situata sottovento rispetto al campus; di conseguenza, l'area di riscaldamento varia al variare della direzione del vento.

FIGURA 5: ESTENSIONE DELLE AREE CON POTENZIALE AUMENTO DI TEMPERATURA A TUTTE LE DIREZIONI DEL VENTO



Thermo-aerodynamics study

Milano Data Center Campus – Heat Island Study

CFD Technical report

N°Case	26.032	Stage	Study
Reference	Milano Data Center Campus – Heat island study		
Title	CFD technical report		

Ind.	Date	Diffusion	Written by	Validated by
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1. General description of the study

1.1. Context

EOLIOS has been commissioned to perform an urban heat island (UHI) CFD analysis for the Equinix data center campus located in Milan. The objective of the study is to evaluate the impact of data center heat rejection on the surrounding urban environment, with a particular focus on near-ground air temperatures in the vicinity of the campus.

The Equinix campus considered in this study consists of seven data center buildings, identified as ML5, ML6, ML7, ML8, ML9, ML10 and ML11. The analysis includes all associated rooftop and outdoor heat rejection systems contributing to the thermal emissions of the site.

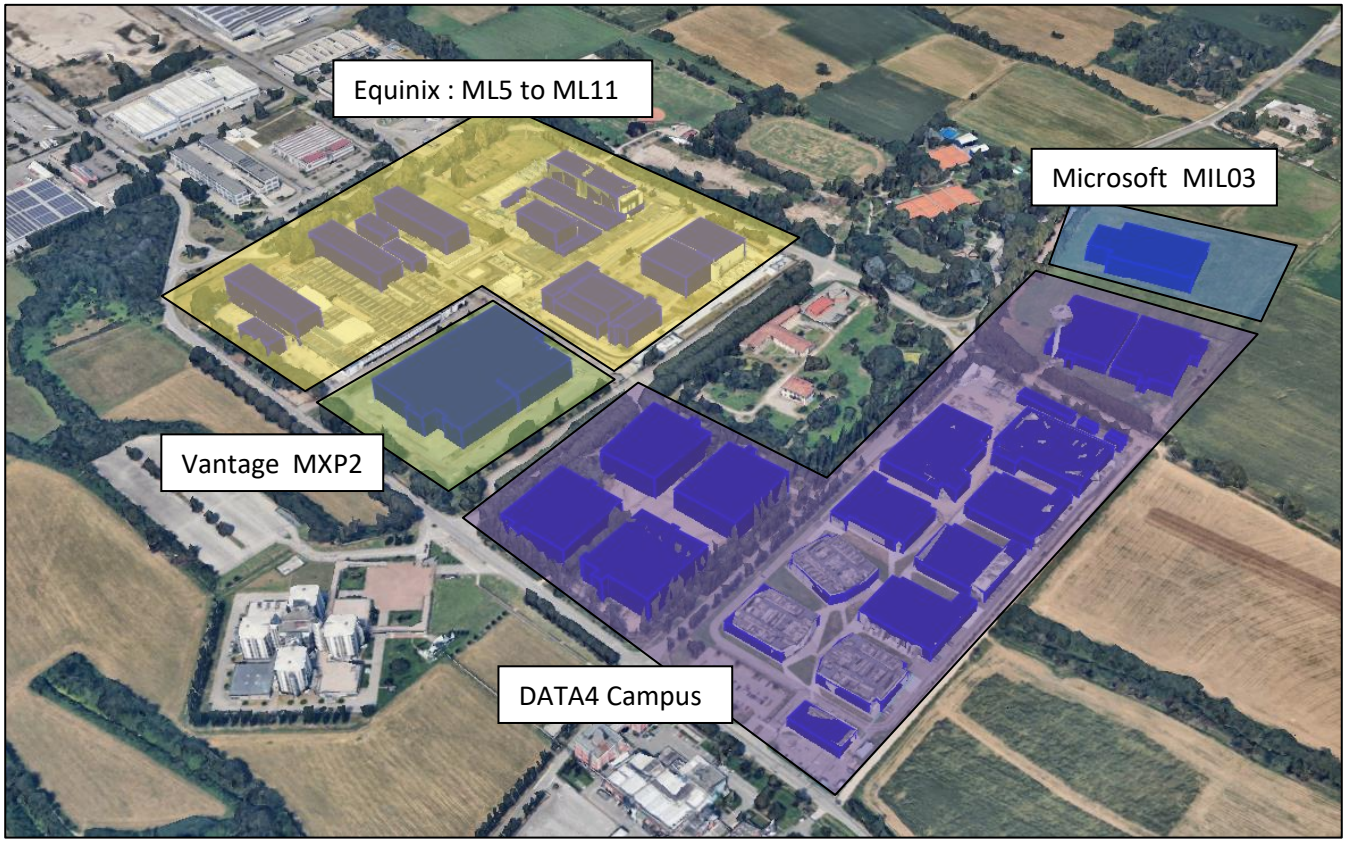

Figure – Aerial view of the Equinix campus in Milan and surrounding data center developments

The study will investigate the thermal influence of the Equinix campus under different urban development configurations through several comparative simulation scenarios:

- **Baseline scenario ("Before")**: simulation of the site without any data center development.
- **Scenario 1 ("After – Equinix only")**: simulation including only the Equinix campus and its associated heat rejection systems.
- **Scenario 2 ("After – Full data center cluster")**: simulation including the Equinix campus together with the neighboring data center campuses operated by DATA4, Microsoft and Vantage Data Centers.

The CFD analysis aims to quantify the cumulative thermal impact generated by these facilities and assess the formation of localized urban heat islands around the site. The simulations will consider prevailing meteorological conditions based on observations from the Milano Linate Airport weather station.

1.2. Objectives of the Study

The CFD study aims to:

- Quantify the impact of the Equinix campus on ambient air temperatures at pedestrian level in the surrounding area.
- Compare thermal conditions between the baseline situation (without data centers) and the different development scenarios.
- Evaluate the cumulative urban heat island effect generated by the concentration of multiple data center campuses in the area.
- Assess how prevailing wind conditions influence heat dispersion and temperature accumulation around the campuses.
- Identify zones of elevated ground-level temperatures resulting from heat rejection systems.
- Analyze the interaction between the Equinix campus and neighboring facilities, including DATA4, Microsoft, and Vantage Data Centers.
- Provide recommendations to mitigate the thermal impact of the campuses on the local urban environment where necessary.
- Establish a comparative “before/after” assessment framework to support environmental evaluation of the project development.

2. CFD Numerical Modeling

2.1. General

Computational Fluid Dynamics (CFD), more often referred to as Computational Fluid Dynamics (CFD), consists of all the numerical methods used to study a fluid flow in a given environment.

These flows are governed by partial differential equations. Since these equations are analytically insolvable, the finite element calculation method makes it possible to solve them numerically: this makes it possible to have an approximate solution to a physical problem.

A CFD study, when applied to buildings, can provide the designer with information about the likely air velocities, pressures, and temperatures that will occur in and around building spaces.

Specified boundary conditions may include building-induced aeraulic effects, internal heat gains from processes and climate treatment systems...

CFD simulations make it possible to study the design of ventilation and air conditioning of large volumes, in order to ensure that the air inlets and outlets allow the room to be properly ventilated and to ensure optimal comfort.

2.2. Principle of boundary conditions

To solve the partial differential equations, we need to specify the boundary conditions of the calculation.

The boundary conditions are defined in part during the on-site measurement campaign and according to the information collected from the project manager.

We will study the project in a volume open to the outside in a steady state. For this type of study, it is generally a question of defining:

The type of walls:

- The type of material, its physical properties, heat loss...
- If it is a perfectly slippery wall or if viscosity must be taken into account,
- The wall temperature and possibly the heat exchange coefficient if the heat equation is solved without automatic calculation of the convective exchanges.

On surfaces open to the outside (fluid boundary condition):

- If it is an entrance or an exit (the flow is one-way),
- impose a velocity field or a flow rate, or impose an average static pressure...
- Impose a uniform temperature or enthalpy flow.
- Specify surface coefficients (if necessary) to simulate heat transfer to the surrounding environment through exterior surfaces.

The blowing points of the systems will be modelled precisely. Each blowing point will be modeled from its location and taking into account the blowing temperatures.

Taking into account internal inputs:

- Input of W inputs on predefined volumes or according to surface temperature.
- The input of thermal systems, ventilation system specific to the study areas to be refined.

When defining boundary conditions, the stability of the calculation must be taken into account: the solution of the equations is approximate, in several steps, and it is important that we get closer to the solution at each step (see calculation method).

2.3. Principle of the mesh

Mathematical simulation of airflow and heat transfer processes includes the numerical solution of a set of second-order, non-linear, partial differential equations.

Since the numerical model of spaces is composed of an infinite number of points, it is impossible to solve partial differential equations, even numerically. The structure is therefore cut into a finite number of points which results in a decomposition of the geometry into a simple form. All of these nodes and elements make up the model mesh.

The software performs a complete topological query of the analysis geometry and determines the mesh size and distribution on each edge, surface, and in the volume of the model. Geometric curvature, gradients, and proximity to neighboring geometry are considered when assigning element sizes and when distributing the mesh. The mesh is then systematically refined by the engineers in charge of the studies in the specific study areas and with a high gradient.

The mesh is automatically generated according to the geometry of the model and from the boundary conditions by the use of algorithms (5-type Petrov-Garlerkin advection method) defining the optimal convergence solution.

The studies are carried out with about 60 million fluid elements.
The mesh is of the hybrid type. The elements of this type of mesh are generated without any constraint as to their layout, allowing to generate a complex geometry while maintaining a good quality of the elements. The resulting mesh combines a mixture of elements of different types, tetrahedral, prismatic or pyramidal in 3D. It combines the advantages of structured and unstructured meshes.

In each of these volumes, the conservation equations are expressed as algebraic equations. This set of finite volumes is referred to as the mesh**.**

The grid is composed for studies of about 60,000,000 unstructured fluid elements (tetrahedra, pyramids and prisms) with mesh refinement on the surface of the heat sources and in the input and output regions in order to properly take into account these phenomena at the local level. The fine mesh is a determining factor in the quality of studies; but can lead to very high resolution times (here the resolution time is more than 40 hours of digital processing).

The engineers made specific mesh refinement in certain areas in order to optimize the density of the meshes in the model.

In the CFD model, the walls of the project are perfectly watertight, which means that there are no gaps other than those deliberately depicted in the envelope. Thus, air inlets in buildings linked to defects in the tightness of the envelope (holes, network passages, etc.) are not taken into account.

2.4. Numerical simulation

The solver of the code used solves the equations at each node of the mesh in an approximate way, respecting the fundamental principles of physics (conservation of mass and energy).

The notion of turbulence model is predominant in fluid mechanics. It makes it possible to catalog the different structures that coexist in a flow and to give them a certain importance within the flow. The most widely used turbulence models in CFD codes today are the 2-equation models and particularly the so-called standard k-e turbulence model which is by far the most widespread. The k-e model is used for all document studies.

Standard K-Epsilon Model:
The k-epsilon model is a widely used model based on the equations of turbulent kinetic energy transport and dissipation. The k-epsilon model solves for two variables: "k" the turbulent kinetic energy and "epsilon": the rate of kinetic energy dissipation. The k-epsilon model is the most popular for industrial and HVAC applications due to its good convergence speed and acceptable memory requirements.

This turbulence model is particularly effective in dealing with external and internal flow issues around complex geometries for standard air flows and velocities in the building.

2.5. Calculation methodology

The heat transfer to the surface of the servers is active. External gains related to the weather (solar and temperature) are taken into account for the walls facing the outside.

We will carry out these studies by considering air as an incompressible fluid in a steady state (time-independent boundary condition) for standard scenarios. This calculation methodology is particularly suitable for the data center given the 24-hour usage process.

CFD studies require complex parameterization and take into account many modeling assumptions. These studies should be read as a decision-making tool and verification in the sizing and understanding of the phenomena, they cannot exhaustively represent all climatic and usage configurations.

2.6. Concept of convergence in CFDs

The finite element method is an approximate solution to a problem: it is necessary to verify the accuracy of the calculation by validating the convergence of the mesh and the consistency of the results (continuity of deformations in the material, etc.).

To define the notion of convergence, it is necessary to study the small and large frequency variations throughout the field of the solution and to evaluate the local and global fluctuations of each degree of freedom between each iteration. The minimum, maximum, and mean value of all dependent variables is examined, so when the maximum instantaneous slope in all these data is less than the defined level, the solution is stopped (this is called a converged solution).

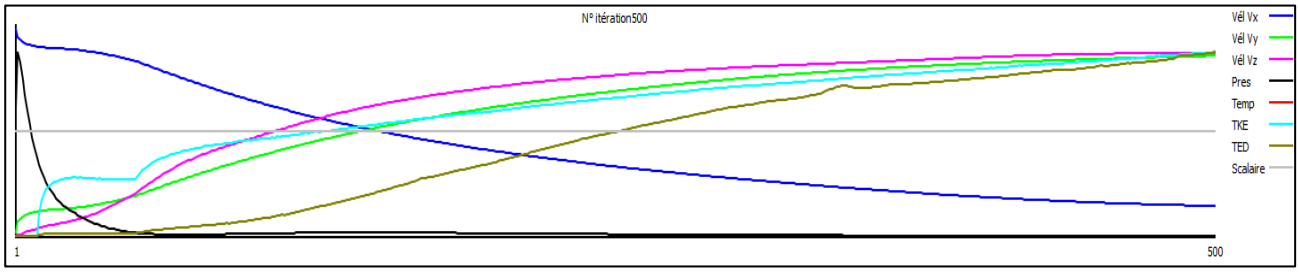

Figure – Illustration of the convergence diagram

The calculation is controlled by the engineers in charge of the studies in order to stabilize the solution of the equations. When deemed necessary, manual under-relaxation controls (lower iterative value for a more stable, but slower, computation) are applied.

All studies presented in this document have been audited and are considered to have converged at the Dphi/phi 10^-4 ratio

3. Meteorological study

3.1. Weather station

ASHRAE (the American Society of Heating, Refrigerating and Air-Conditioning Engineers) is an international organization that establishes standards, guidelines, and best practices in the fields of heating, ventilation, air conditioning, and refrigeration (HVAC-R). It aims to promote energy efficiency, environmental comfort, and sustainability in buildings by providing research, publications, and training for industry professionals. ASHRAE is a key reference for engineers and designers of air conditioning and refrigeration systems.

ASHRAE compiles meteorological data from thousands of stations worldwide. This provides reliable and representative information on local climatic conditions, which is essential for properly sizing systems according to real environmental conditions. In addition, this data is based on long-term averages (25 years) and extremes calculated over extended periods (up to 50 years), ensuring reliability and accuracy for designers. It includes average annual and monthly temperatures as well as extreme temperatures (maximum and minimum), allowing realistic scenario forecasting.

This database also provides design temperature data for the hottest and coldest days, enabling reliable estimation of extreme conditions while avoiding oversizing. As a result, ASHRAE data offers a standardized, reliable global reference required to design efficient and sustainable outdoor systems capable of performing under a wide range of climatic conditions.

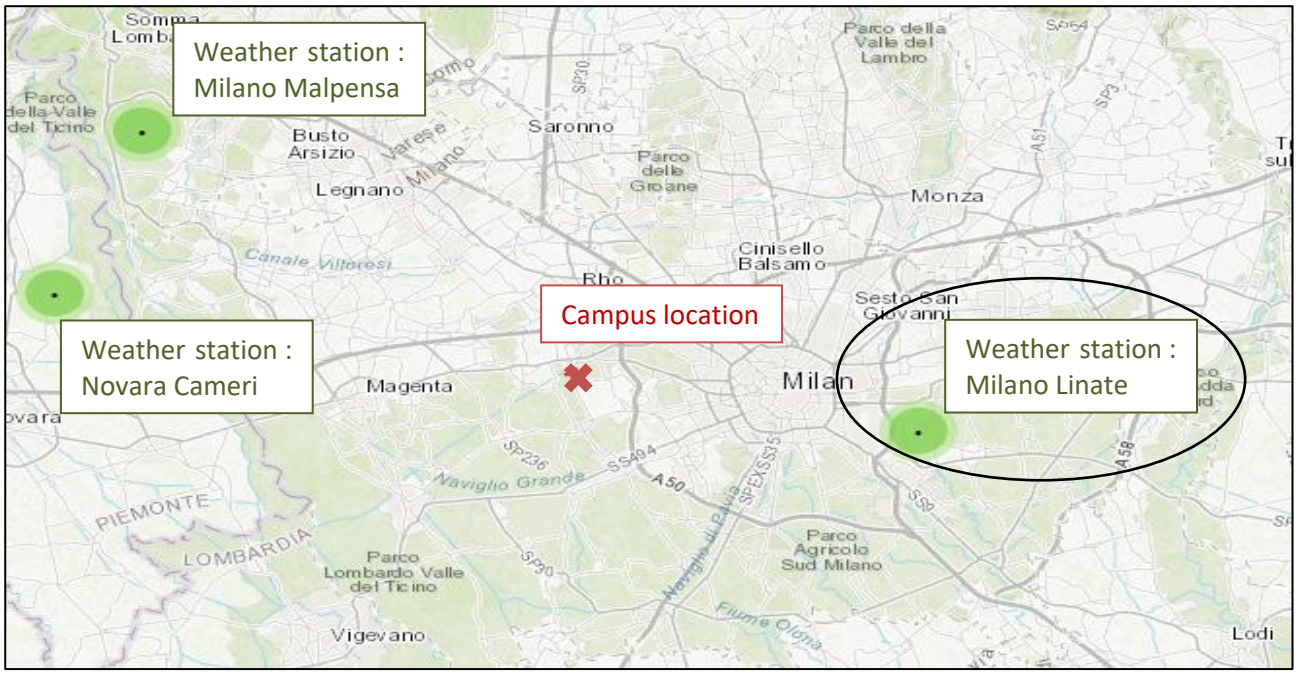

Figure – Campus Location and Nearest Weather Station

The meteorological study carried is based on the Milano Linate station (17 km away from the site) and is carried out to determine the temperature conditions to be used for the simulations. In terms of temperature and wind, all the scenarios are based on the 2025 ASHRAE temperature and wind.

3.2. Temperature study

2025 ASHRAE Handbook — Fundamentals (SI) © 2025 ASHRAE, Inc.

MILANO LINATE, Italy WMO: **160800**

Lat: **45.445N** Lon: **9.277E** Elev: **108** StdP: **100.04** Time Zone: **1.00 (EUC)** Period: **1999-2023** Grade: **A** WBAN: **99999**

Annual Heating, Humidification, and Ventilation Design Conditions

Coldest Month	Heating DB		Humidification DP/MCDB and HR						Coldest Month WS/MCDB				MCWS/PCWD to 99.6% DB		WSF
			99.6%			99%			0.4%		1%				
	99.6%	99%	DP	HR	MCDB	DP	HR	MCDB	WS	MCDB	WS	MCDB	MCWS	PCWD	
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)	(n)	(o)	(p)
1	-4.0	-2.6	-11.3	1.4	5.0	-8.7	1.8	4.0	8.1	10.7	6.2	9.2	0.7	210	0.384

Annual Cooling, Dehumidification, and Enthalpy Design Conditions

Hottest Month	Hottest Month DB Range	Cooling DB/MCWB						Evaporation WB/MCDB						MCWS/PCWD to 0.4% DB	
		0.4%		1%		2%		0.4%		1%		2%			
		DB	MCWB	DB	MCWB	DB	MCWB	WB	MCDB	WB	MCDB	WB	MCDB	MCWS	PCWD
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)	(n)	(o)	(p)
7	10.5	33.8	23.6	32.5	22.8	31.3	22.1	25.1	31.2	24.1	30.2	23.2	29.3	2.1	220

Dehumidification DP/MCDB and HR									Enthalpy/MCDB						Extreme Max WB
0.4%			1%			2%			0.4%		1%		2%		
DP	HR	MCDB	DP	HR	MCDB	DP	HR	MCDB	Enth	MCDB	Enth	MCDB	Enth	MCDB	
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)	(n)	(o)	(p)
23.2	18.2	28.7	22.1	17.0	27.4	21.2	16.0	26.6	76.7	31.0	72.4	30.1	68.9	29.2	29.0

Extreme Annual Design Conditions

Extreme Annual WS				Extreme Annual Temperature				n-Year Return Period Values of Extreme Temperature							
				Mean		Standard Deviation		n=5 years		n=10 years		n=20 years		n=50 years	
1%	2.5%	5%		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
(a)	(b)	(c)		(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)	(n)	(o)	(p)
6.3	4.9	4.1	DB	-6.3	35.7	2.0	1.2	-7.8	36.6	-9.0	37.3	-10.1	38.0	-11.6	38.8
			WB	-7.0	25.9	2.1	1.4	-8.5	26.9	-9.8	27.7	-10.9	28.5	-12.5	29.5

Figure – Average maximal annual temperature

It appears that the ASHRAE average maximal annual temperature is 35.7°C. It is the external temperature that will be use for the simulation.

3.3. Direction study

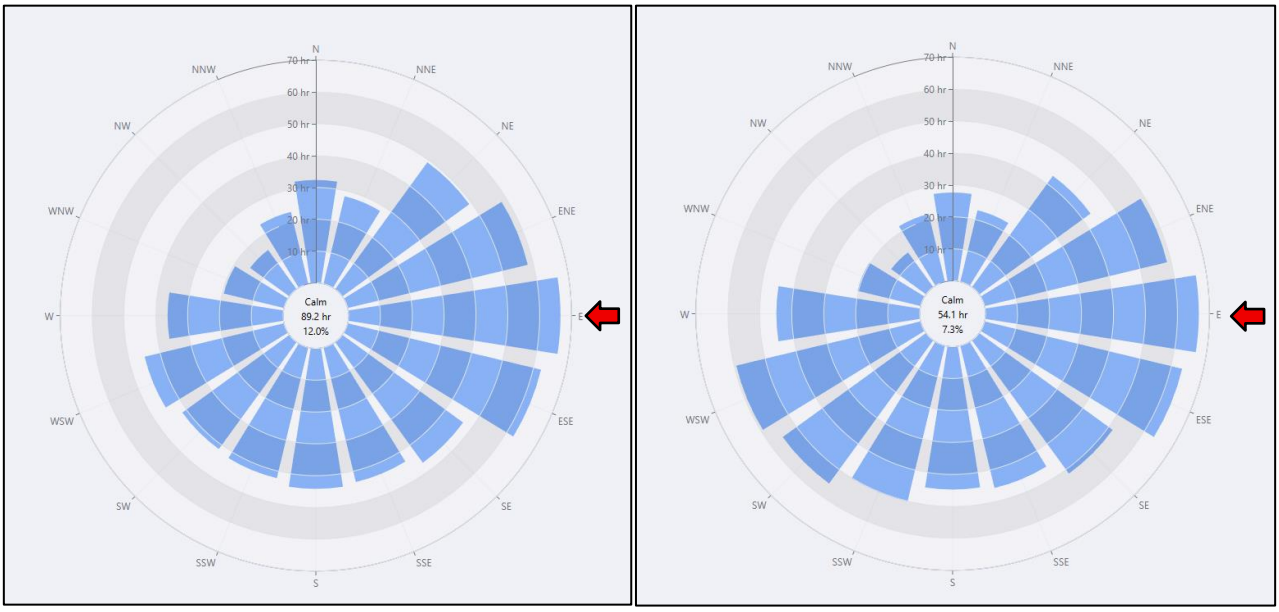

Figure – Annual wind rose – Milano Linate – July and August

Based on data from the weather station Milano Linate Airport, the predominant wind directions considered for Milan is the easterly wind (E), blowing from 90°. This prevailing wind represent the dominant airflow pattern observed at the Milano Linate meteorological station and is commonly used as reference directions for local climatic and environmental analyses.

3.4. Velocity study

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MILANO LINATE, Italy WMO: **160800**

Lat: **45.445N** Lon: **9.277E** Elev: **108** StdP: **100.04** Time Zone: **1.00 (EUC)** Period: **1999-2023** Grade: **A** WBAN: **99999**

Monthly Climatic Design Conditions

		Annual (d)	Jan (e)	Feb (f)	Mar (g)	Apr (h)	May (i)	Jun (j)	Jul (k)	Aug (l)	Sep (m)	Oct (n)	Nov (o)	Dec (p)
Temperatures and Degree-Days	DBAvg	14.6	3.7	5.7	10.1	14.1	18.9	23.4	25.3	24.7	20.5	15.1	9.1	4.3
	DBStd	8.21	2.66	3.09	3.29	3.06	3.14	2.92	2.29	2.64	2.78	3.16	3.19	3.04
	HDD10.0	594	196	122	38	4	0	0	0	0	0	2	54	178
	HDD18.3	2058	453	353	255	129	32	2	0	0	12	109	278	436
	CDD10.0	2282	1	2	42	128	274	403	475	456	315	159	26	1
	CDD18.3	703	0	0	0	3	48	154	217	198	76	7	0	0
Wind	WSAvg	1.6	1.3	1.6	1.9	2.0	2.0	1.9	1.9	1.6	1.4	1.2	1.3	1.2

Figure – Maximal monthly average wind velocity

The selected wind speed corresponds to the highest monthly average wind speed recorded during the year, which is 2 m/s in May according to observations from the Milano Linate Airport meteorological station. A maximum instantaneous wind speed was not considered, as it would not be representative of realistic critical conditions. First, maximum wind speed and maximum air temperature do not occur simultaneously, making such a combination unrealistic for atmospheric dispersion studies. Second, average wind conditions are generally more unfavorable for pollutant dispersion. Very low wind speeds tend to generate vertical plume rise, which promotes upward dispersion and therefore reduces ground-level concentrations. Conversely, excessively high wind speeds strongly dilute and disperse the plume, also leading to more favorable conditions. The most critical scenario therefore corresponds to intermediate wind conditions, represented here by the highest monthly average wind speed of 2 m/s.

3.5. Conclusion of the meteorological analysis

In conclusion, the following wind scenario have been selected:

	Scenario 2
Temperatures	35.7°C
Wind Direction	East (90°)
Wind speed (m/s)	2.0

Table – Summary of External Conditions

4. Assumptions of the simulations

4.1. General information about buildings

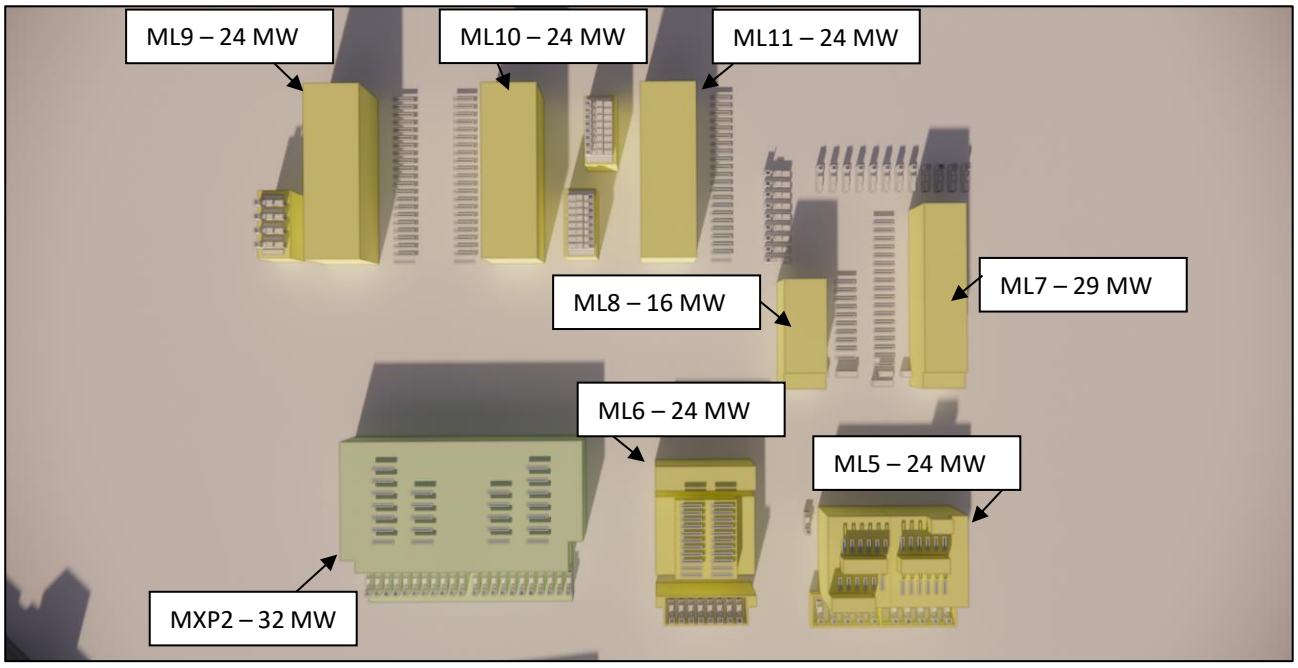


Figure – Name and power of the different data centers in the study area – Equinix and Vantage

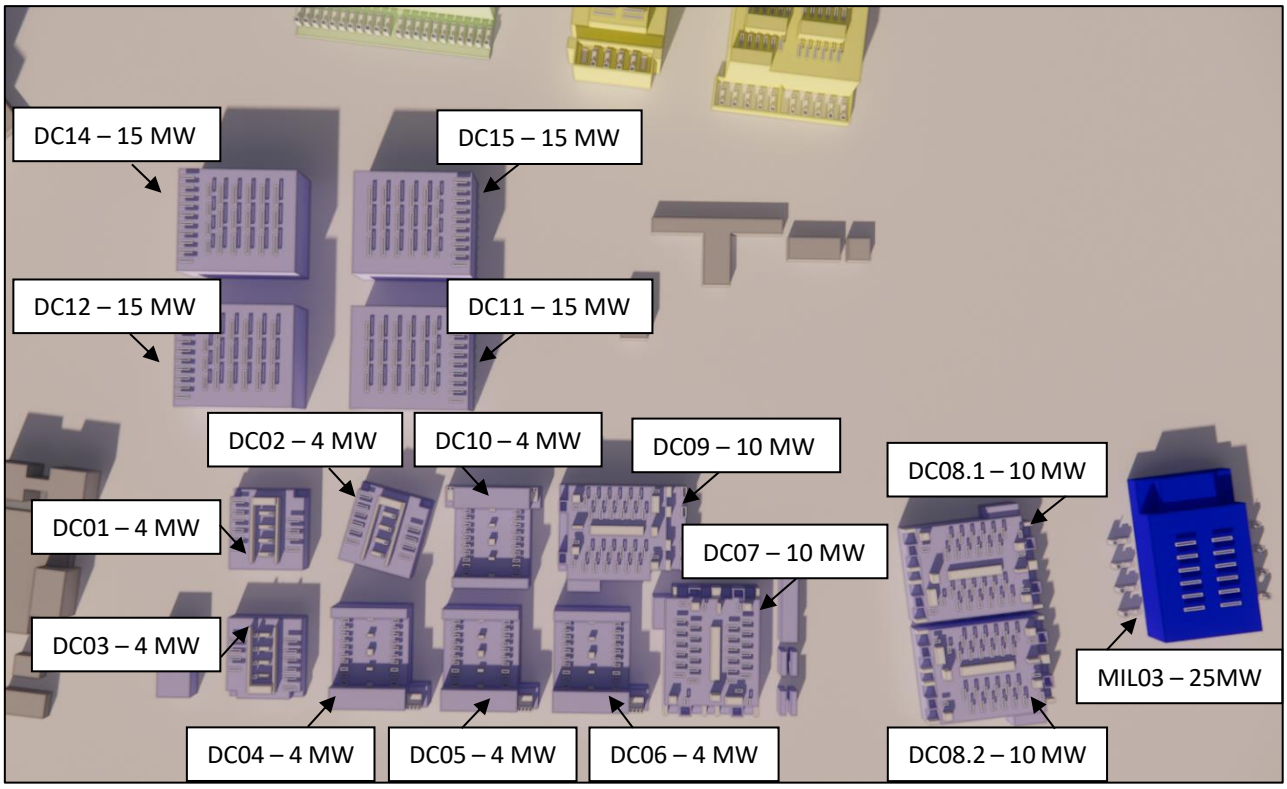


Figure – Name and powers of the different data centers in the study area – DATA4 and Microsoft

4.2. Campus Equinix

4.2.1 Building ML5.1 and ML5.4

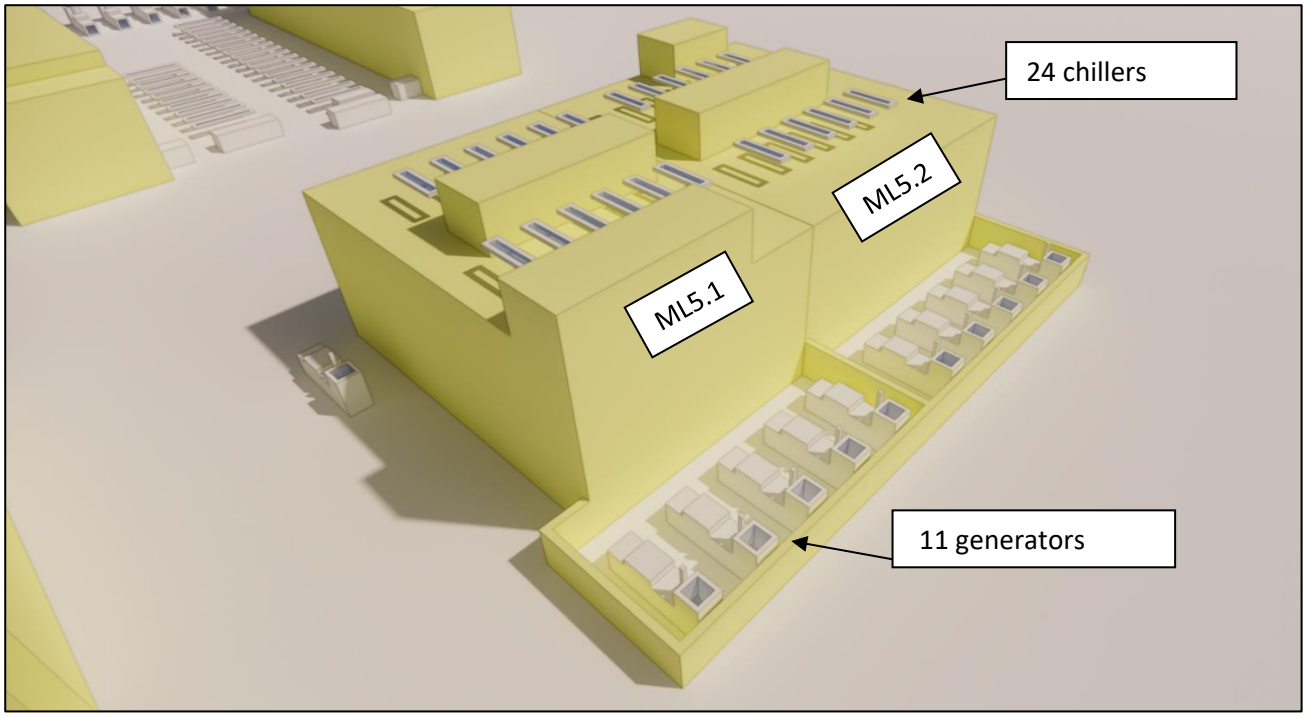


Figure – CFD-Adapted 3D Model – ML5.1 and ML5.4

The data for the chillers in the ML5 building are summarized below.

- Number of chillers: **24**
- Cooling power per chiller: **887.4 kW**
- Total power output per chiller: **1,148.8 kW**
- Total flow rate per chiller: **65.5 m3/s (235,800 m3/h)**
- Number of fans per chiller: **14**

The data from the ML5 building generators are summarized below.

- Number of generators: **11**
- Fan dissipation: **2,315 kW**
- Fan flow rate: **2,534 m3/min (152,040 m3/h)**
- Stack outlet temperature: **484.7 °C**
- Chimney flow rate: **513.5 m3/min (30,810 m3/h)**

4.2.2 Building ML6

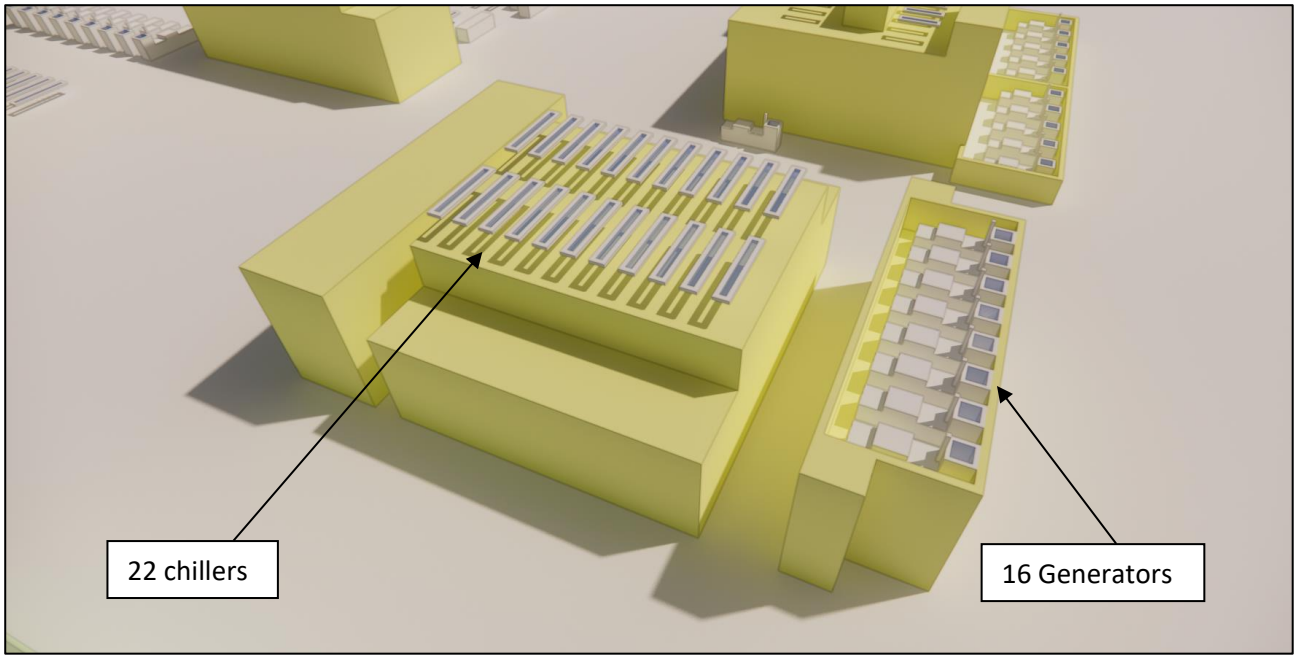


Figure – CFD-Adapted 3D Model – ML6

The data for the chillers in building ML6 are summarized below.

- Number of chillers: **22**
- Cooling power per chiller: **1,473.9 kW**
- Total power output per chiller: **1,530 kW**
- Total flow rate per chiller: **115 m3/s (i.e. 414,000 m3/h)**
- Number of fans per chiller: **22**

The data from the ML6 building generators are summarized below.

- Number of generators: **16**
- Fan power: **2,000 kW**
- Fan flow rate: **2,352 m3/min (or 141,120 m3/h)**
- Stack outlet temperature: **404 °C**
- Chimney flow rate: **552 m3/min (33,120 m3/h)**

4.2.3 Building ML7

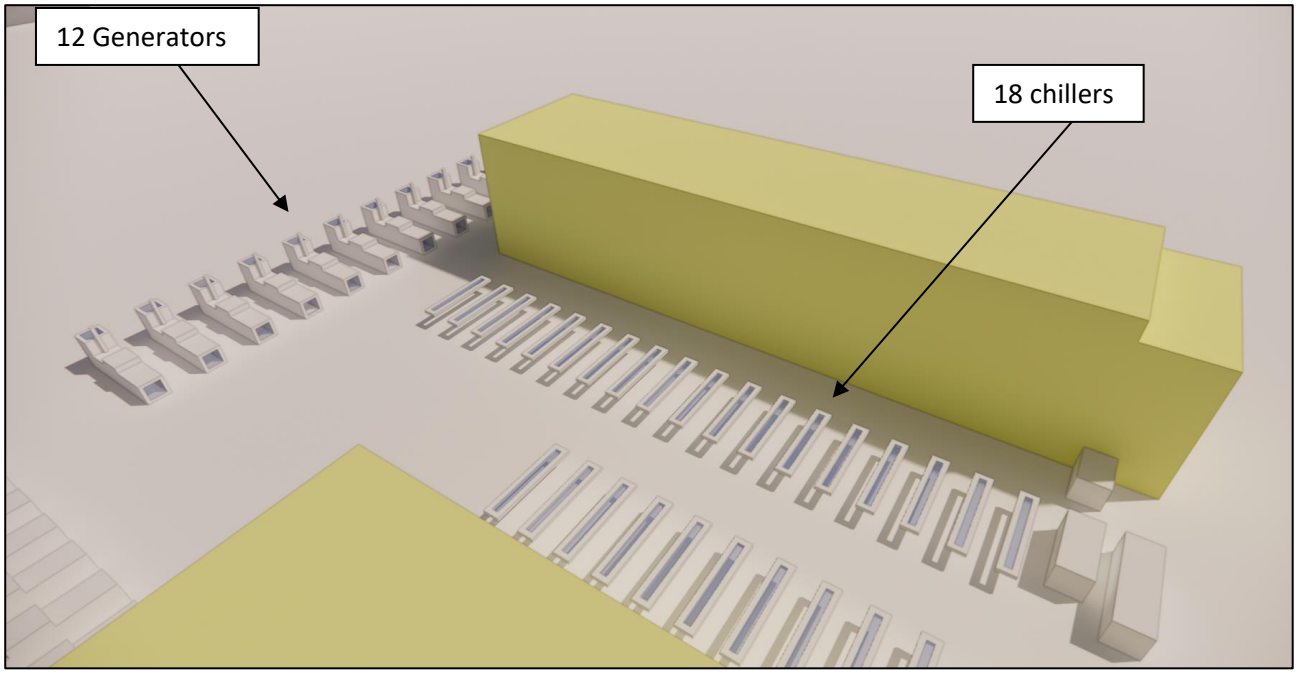


Figure – CFD-Adapted 3D Model – ML7

The data for the chillers in the ML7 building are summarized below.

- Number of chillers: **18**
- Cooling power per chiller: **1,473.9 kW**
- Total power output per chiller: **1,530 kW**
- Total flow rate per chiller: **115 m3/s (i.e. 414,000 m3/h)**
- Number of fans per chiller: **22**

The data from the generators in the ML7 building are summarized below.

- Number of generators: **12**
- Fan power: **1,654 kW**
- Fan flow rate: **1,945 m3/min (or 116,676 m3/h)**
- Stack outlet temperature: **404 °C**
- Chimney flow rate: **456 m3/min (27,383 m3/h)**

4.2.4 Building ML8

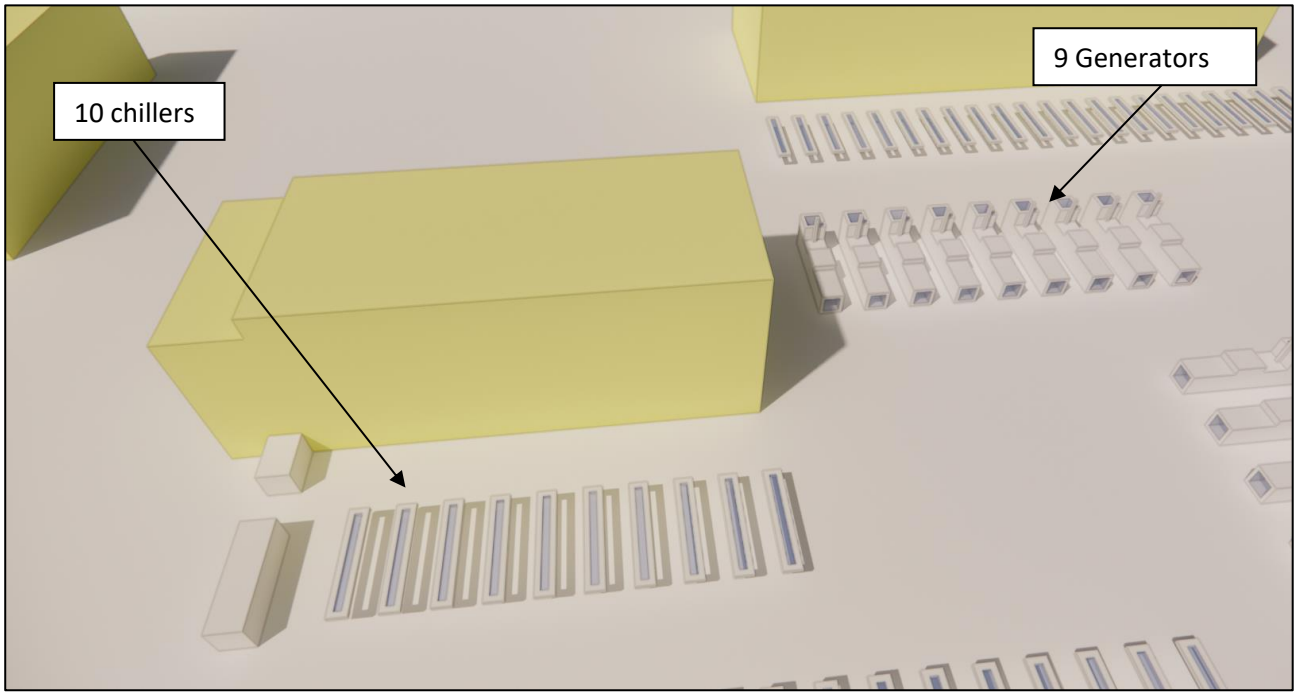


Figure – CFD-Adapted 3D Model – ML8

The data for the chillers in the ML8 building are summarized below.

- Number of chillers: **10**
- Cooling power per chiller: **1,473.9 kW**
- Total power output per chiller: **1,530 kW**
- Total flow rate per chiller: **115 m3/s (i.e. 414,000 m3/h)**
- Number of fans per chiller: **22**

The data from the ML8 building generators is summarized below.

- Number of generators: **9**
- Fan power: **2,000 kW**
- Fan flow rate: **2,352 m3/min (or 141,120 m3/h)**
- Stack outlet temperature: **404 °C**
- Chimney flow rate: **552 m3/min (33,120 m3/h)**

4.2.5 Building ML9, ML10 and ML11

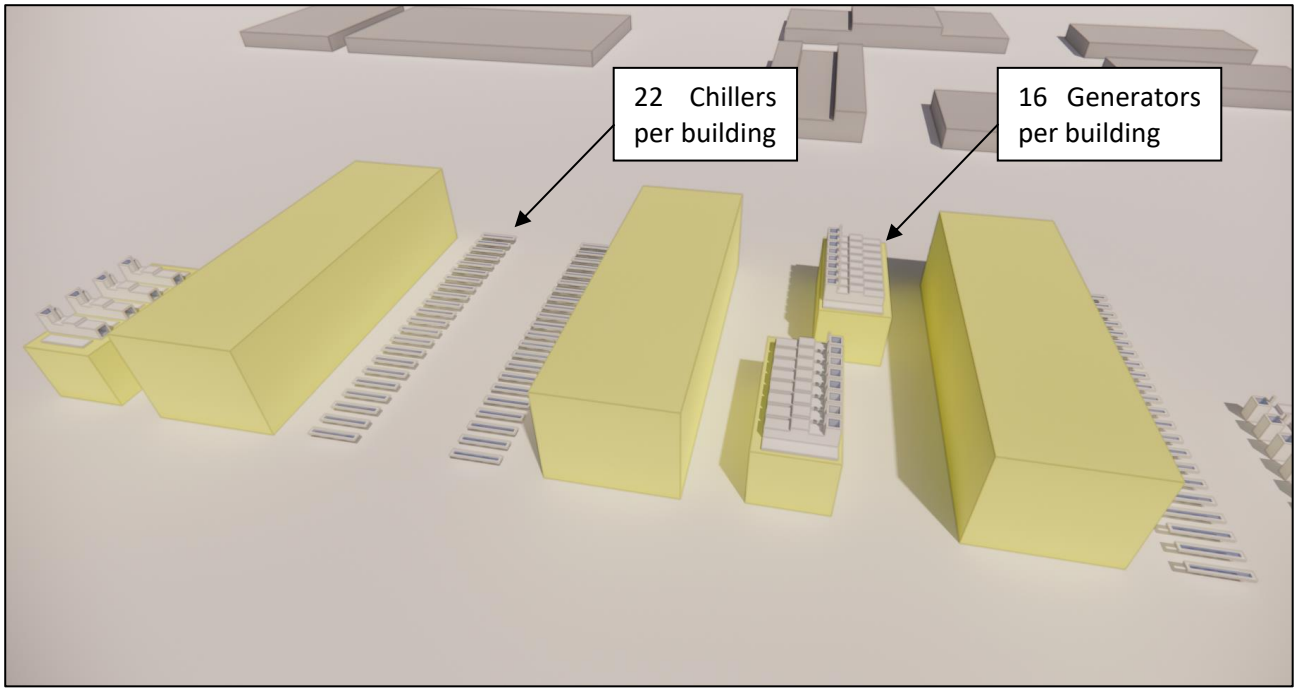


Figure – CFD-Adapted 3D Model – ML9, ML10 and ML11

The data for the chillers of buildings ML9, ML10 and ML11 are summarized below.

- Number of chillers per building: **22**
- Cooling power per chiller: **1,473.9 kW**
- Total power output per chiller: **1,530 kW**
- Total flow rate per chiller: **115 m3/s (i.e. 414,000 m3/h)**
- Number of fans per chiller: **22**

The data from the generators of the ML9, ML10 and ML11 buildings are summarized below.

- Number of generators per building: **16**
- Fan power: **2,000 kW**
- Fan flow rate: **2,352 m3/min (or 141,120 m3/h)**
- Stack outlet temperature: **404 °C**
- Chimney flow rate: **552 m3/min (33,120 m3/h)**

4.3. Campus DATA4

For the surrounding campus (DATA4, Vantage and Microsoft), the power ratings and flow rates of the chillers and gensets are based on the available technical datasheets. Where information was missing, assumptions were made by assimilating them to the power ratings and flow rates of Equinix chillers and gensets, for which all data are known. This approach is detailed in Annex A – Part 5.3.

4.3.1 DC01, DC02 and DC03 buildings

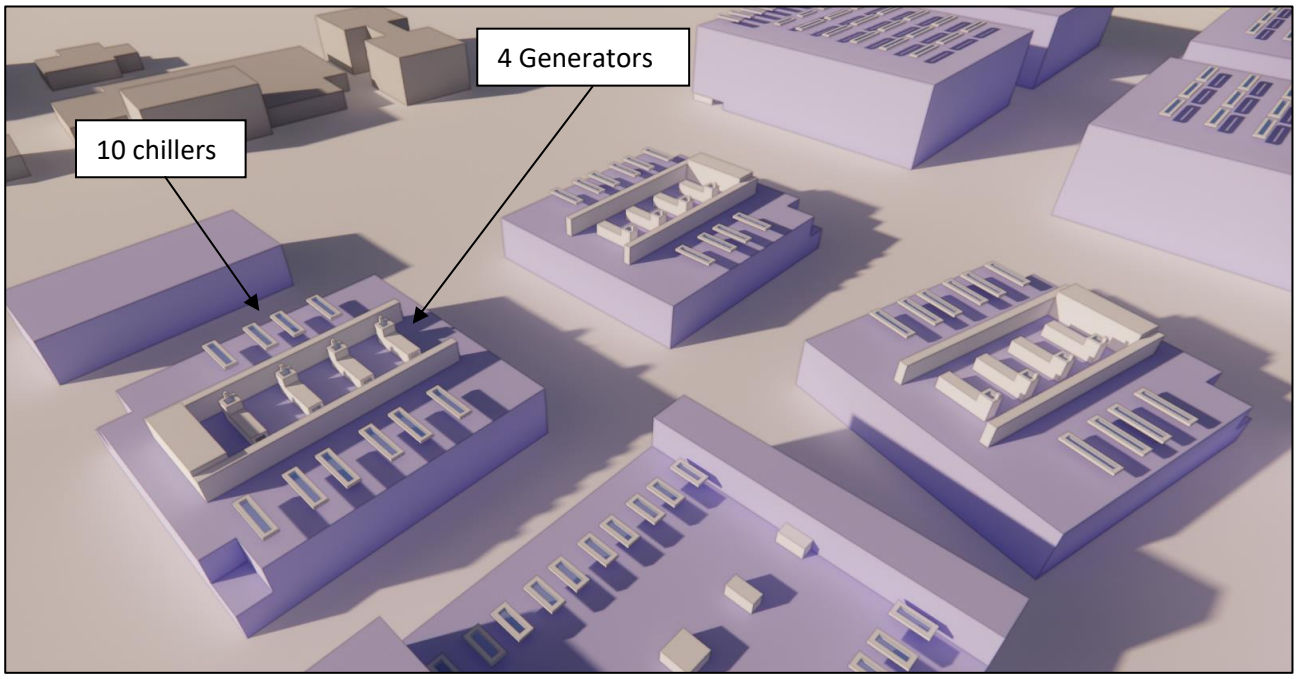


Figure – CFD-Adapted 3D Model – DC01, DC02 and DC03

The data used for buildings DC01, DC02, and DC03 Data4 are as follows:

- Total building power: **4 MW**
- Number of chillers: **10**
- Cooling power per chiller: **887.4 kW**
- Total power output per chiller: **1,148.8 kW**
- Total flow rate per chiller: **65.5 m3/s (235,800 m3/h)**
- Number of generators: **4**
- Power per generator: **2,285 kW**
- Flow rate per generator: **2,688 m3/min (161,280 m3/h)**
- Stack outlet temperature: **404°C**
- Stack flow rate: **631 m3/min (37,851 m3/h)**

4.3.2 Buildings DC04, DC05, DC06 and DC10

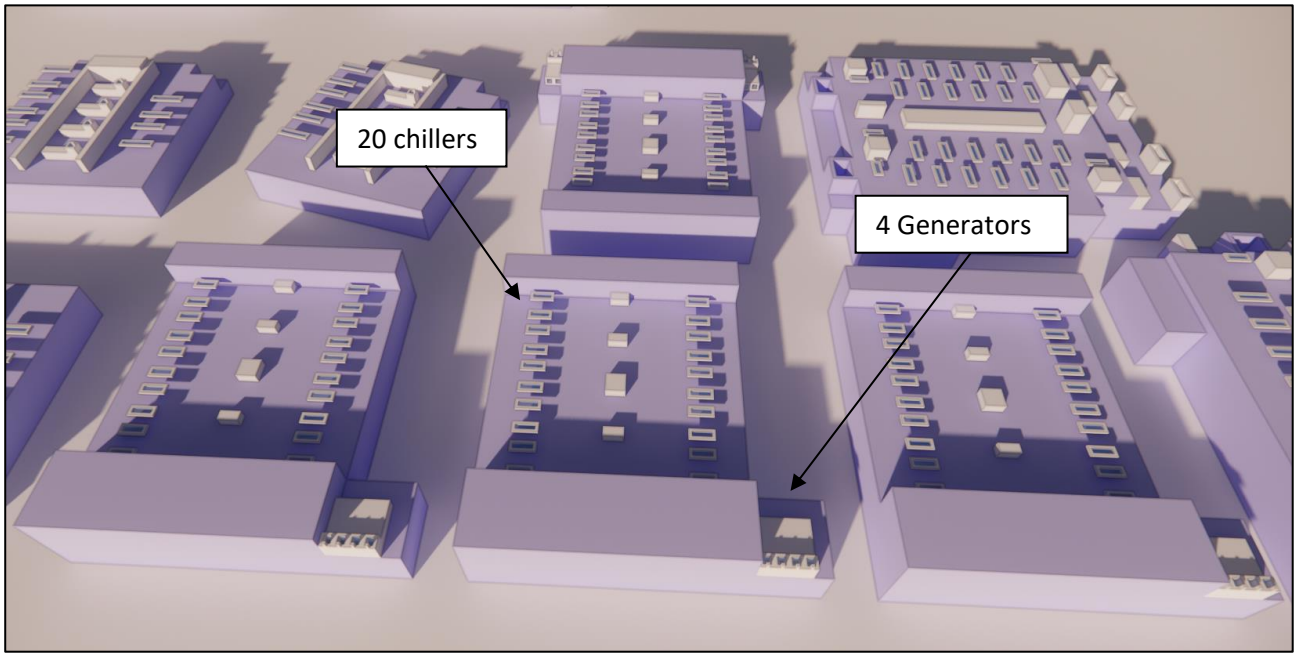


Figure – CFD-Adapted 3D Model – DC04, DC05, DC06 and DC10

The data used for Data4's DC04, DC05, DC06 and DC10 buildings are as follows:

- Total building power: **4 MW**
- Number of chillers: **20**
- Cooling power per chiller: **443.7 kW**
- Total power output per chiller: **574.4 kW**
- Total flow rate per chiller: **32.75 m3/s (i.e. 117,900 m3/h)**
- Number of generators: **4**
- Power per generator: **2,285 kW**
- Flow rate per generator: **2,688 m3/min (161,280 m3/h)**
- Stack outlet temperature: **404°C**
- Stack flow rate: **631 m3/min (37,851 m3/h)**

4.3.3 DC07, DC09, DC08.1 and DC8.2 buildings

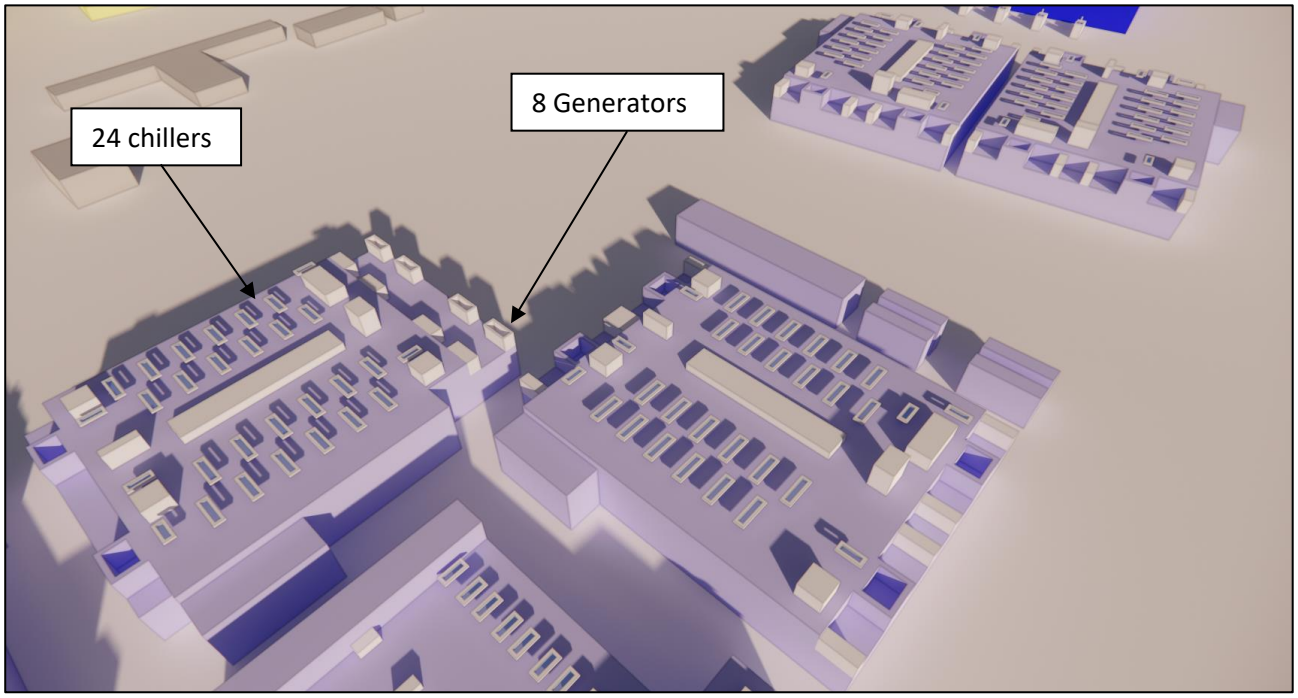


Figure – CFD-Adapted 3D Model – DC07, DC09, DC08.1 and DC08.2

The data used for Data4's buildings D07, DC09, DC08.1 and DC08.2 are as follows:

- Total building power: **10 MW**
- Number of chillers: **24**
- Cooling power per chiller: **887.4 kW**
- Total power output per chiller: **1,148.8 kW**
- Total flow rate per chiller: **65.5 m3/s (235,800 m3/h)**
- Number of generators: **8**
- Power per generator: **2,285 kW**
- Flow rate per generator: **2,688 m3/min (161,280 m3/h)**
- Stack outlet temperature: **404°C**
- Stack flow rate: **631 m3/min (37,851 m3/h)**

4.3.4 Buildings DC11, DC12, DC14 and DC15

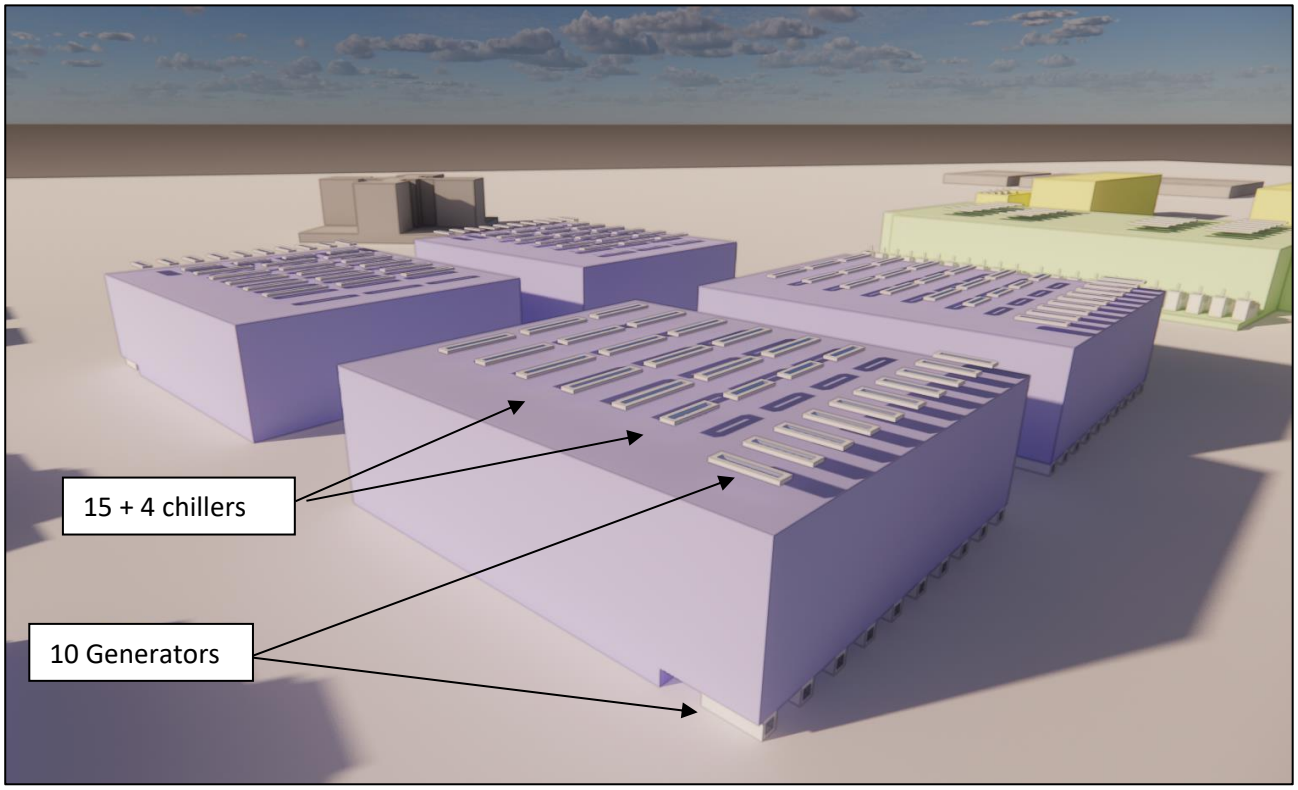


Figure – CFD-Adapted 3D Model – DC11, DC12, DC14 and DC15

The data used for Data4's DC11, DC12, DC14 and DC15 buildings are as follows:

- Total building power: **15MW**
- Number of chillers : **15 big (13m) and 4 small (8.7m)**
- Cooling power per chiller: **1,473.9 and 887.4 kW**
- Total power output per chiller: **1,530 and 1,148.8 kW**
- Total flow rate per chiller: **115.0 and 65.5 m3/s (i.e. 414,000 and 235,800 m3/h)**
- Number of generators: **10**
- Power per generator: **2,285 kW**
- Flow rate per generator: **2,688 m3/min (161,280 m3/h)**
- Stack outlet temperature: **404°C**
- Stack flow rate: **631 m3/min (37,851 m3/h)**

4.4. Campus Vantage – MXP2

For the surrounding campus (DATA4, Vantage and Microsoft), the power ratings and flow rates of the chillers and gensets are based on the available technical datasheets. Where information was missing, assumptions were made by assimilating them to the power ratings and flow rates of Equinix chillers and gensets, for which all data are known. This approach is detailed in Annex A – Part 5.3.

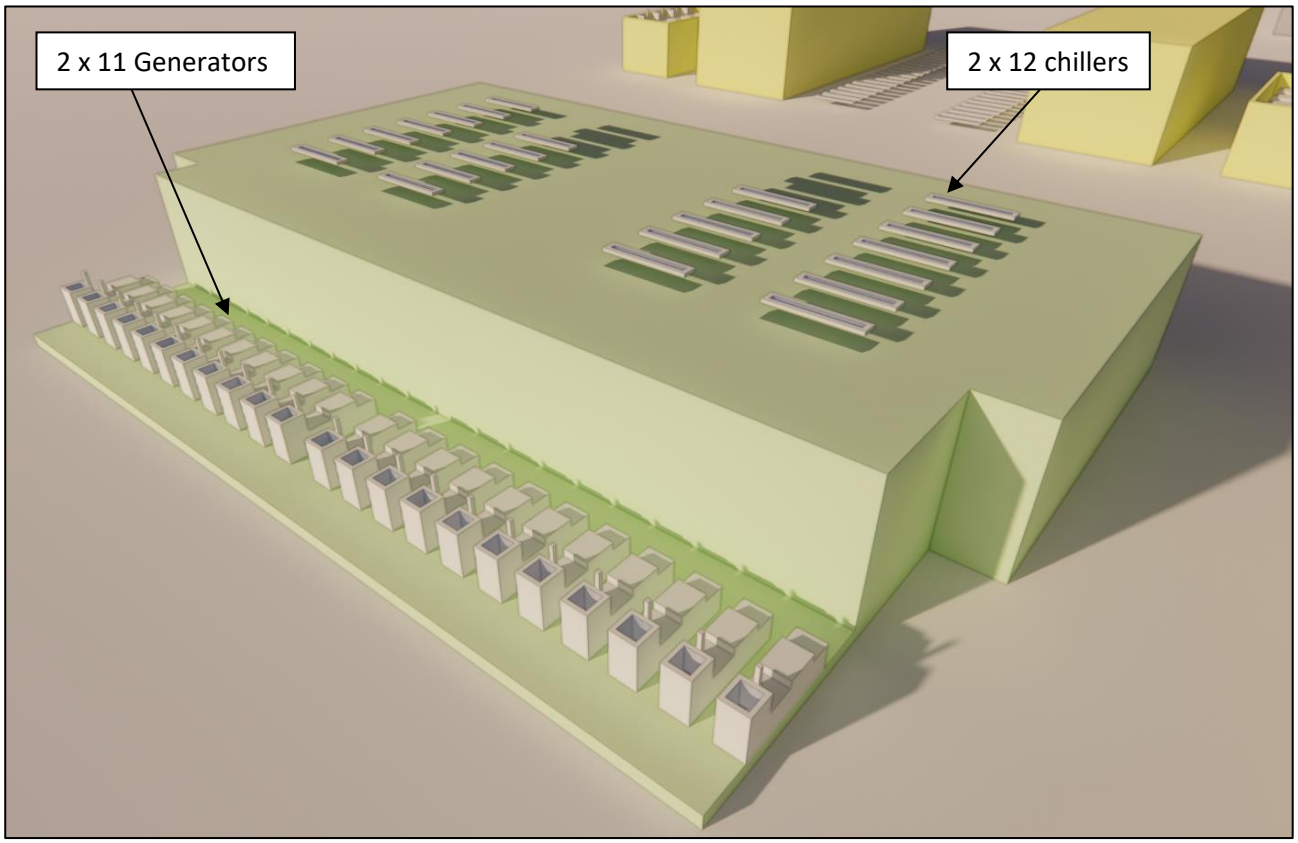


Figure – CFD-Adapted 3D Model – Data Center Vantage MXP2

The data used for Vantage's MXP2 building is as follows:

- Total building power: **32 MW**
- Number of chillers: **24**
- Cooling power per chiller: **1,473.9 kW**
- Total power output per chiller: **1,530 kW**
- Total flow rate per chiller: **115.0 m3/s (or 414,000 m3/h)**
- Number of generators: **22**
- Power per generator: **2,756 kW**
- Flow rate per generator: **2,876 m3/min (i.e. / 172,560 m3/h)**
- Stack outlet temperature: **492°C**
- Stack flow rate: **598.6 m3/min (35,916 m3/h)**

4.5. Campus Microsoft – MIL03

For the surrounding campus (DATA4, Vantage and Microsoft), the power ratings and flow rates of the chillers and gensets are based on the available technical datasheets. Where information was missing, assumptions were made by assimilating them to the power ratings and flow rates of Equinix chillers and gensets, for which all data are known. This approach is detailed in Annex A – Part 5.3.

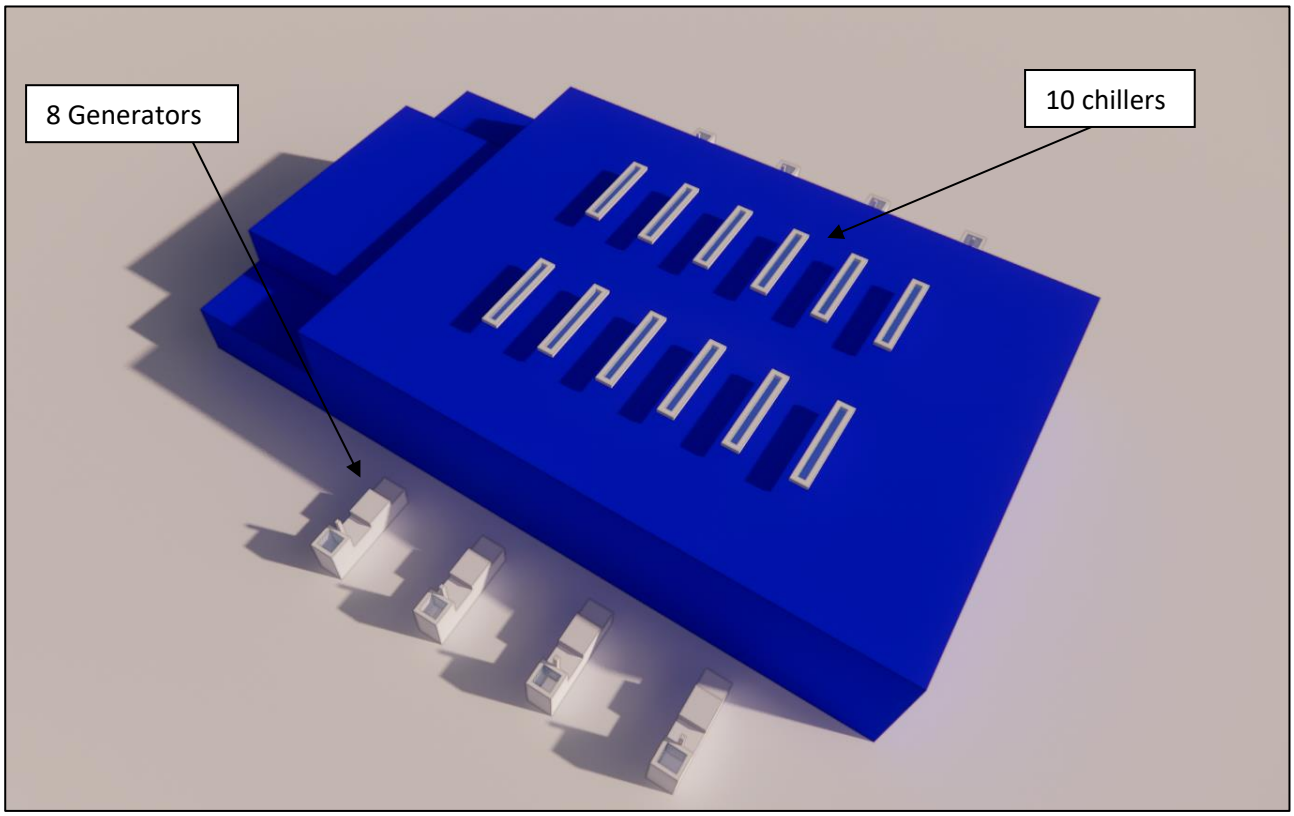


Figure – CFD-Adapted 3D Model – Data Center Microsoft MIL03

The data used for Microsoft's MIL03 building is as follows:

- Total building power: **25 MW**
- Number of chillers: **10**
- Cooling power per chiller: **1,473.9 and 887.4 kW**
- Total power output per chiller: **1,530 and 1,148.8 kW**
- Total flow rate per chiller: **115.0 and 65.5 m3/s (i.e. 414,000 and 235,800 m3/h)**
- Number of generators: **8**
- Power per generator: **2,143 kW**
- Flow rate per generator: **2,520 m3/min (i.e. / 151,200 m3/h)**
- Stack outlet temperature: **404°C**
- Stack flow rate: **591 m3/min (35,460 m3/h)**

4.6. Summary of Study Scenarios

The 3 scenarios detailed below will be launched, with for each of these scenarios an outdoor temperature of 35.7°C and a wind of 2.0 m/s from the East (90°).

- Scenario 1: Current configuration without the data center implementation
- Scenario 2: Equinix Campus Implementation – Considering all chillers and 1 generator for the entire Equinix campus (monthly test case)
- Scenario 3: Equinix Campus Implementation + 3 Adjacent Campuses (Data4, Microsoft and Vantage) – Consideration of all chillers and 1 generator for each campus (monthly test case)

The generators activated will be:

- One generator of ML5 for Equinix (the most central one)
- One generator of DC10 for DATA4 (the most central one)
- One generator of MXP2 for Vantage (the most central one)
- One generator of MIL03 for Microsoft (the most central one)

The chillers will all be considered in operation and at 100% of their capacity.

For each of these scenarios, the impact of the systems on the ground and at the height of adjacent buildings will be studied.

5. Results of the study

5.1. Initial scenario

5.1.1 Temperature plans

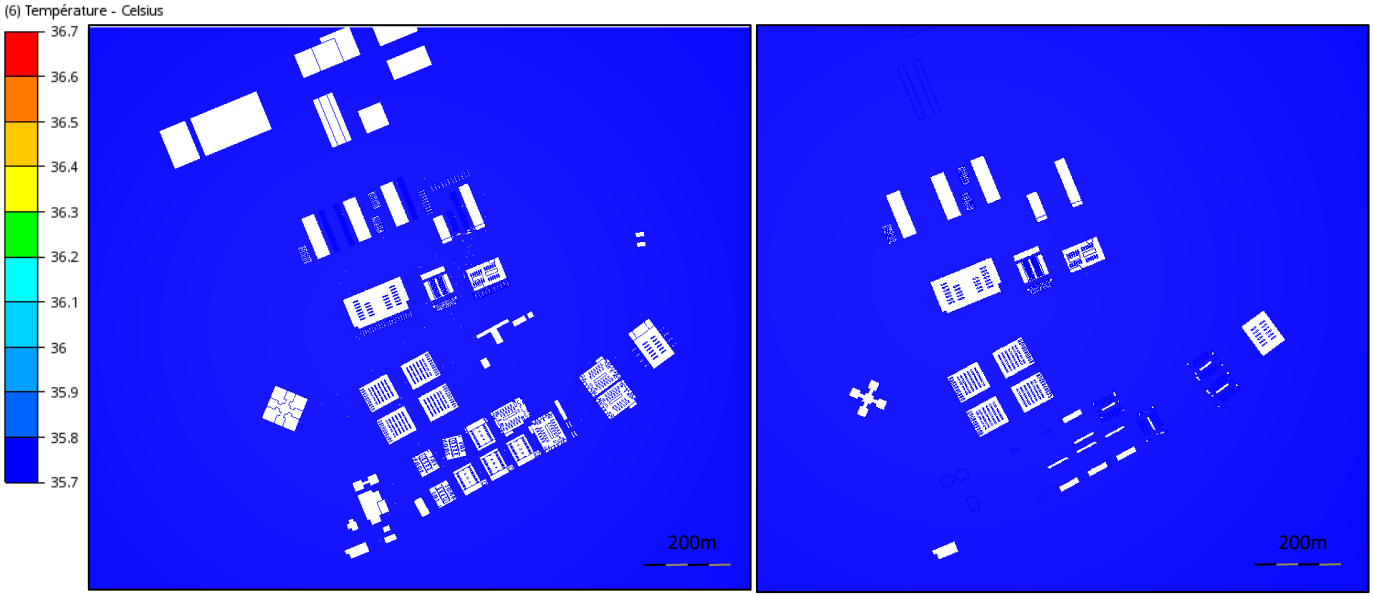


Figure – Temperature plan at 1m and 15m – No data center thermal discharge scenario

In the first configuration (without considering any data center), the ambient temperature is equal to the domain inlet temperature at all points, i.e. 35.7°C.

5.1.2 Pressure plans

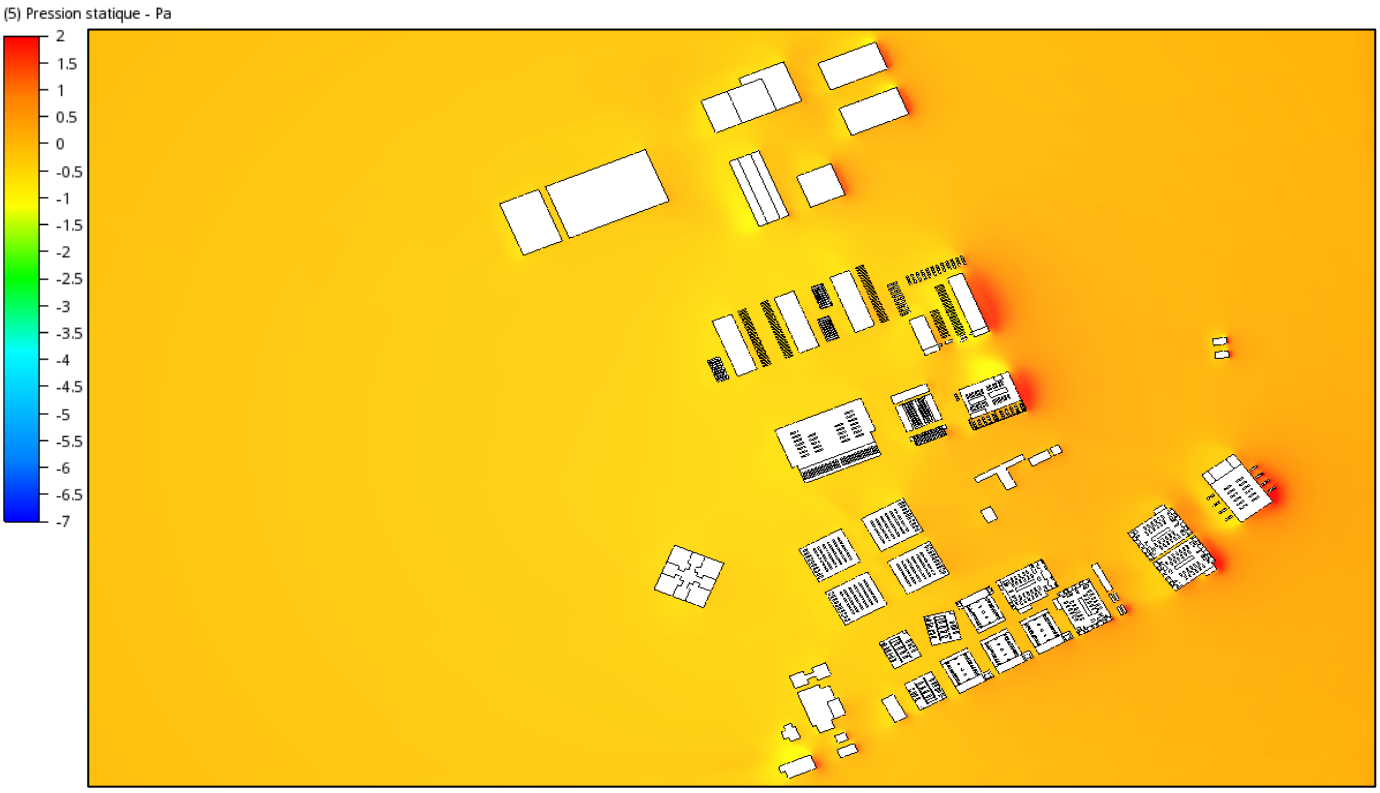


Figure – Pressure plan at 1m - No data center thermal discharge scenario

In the first configuration (without considering any data center), the static pressure varies between 2 and -1 Pa due to wind obstacles. These pressures are too low to influence plumes at Δ = +10°C.

5.2. Scenario with Equinix campus only

5.2.1 Temperature plans

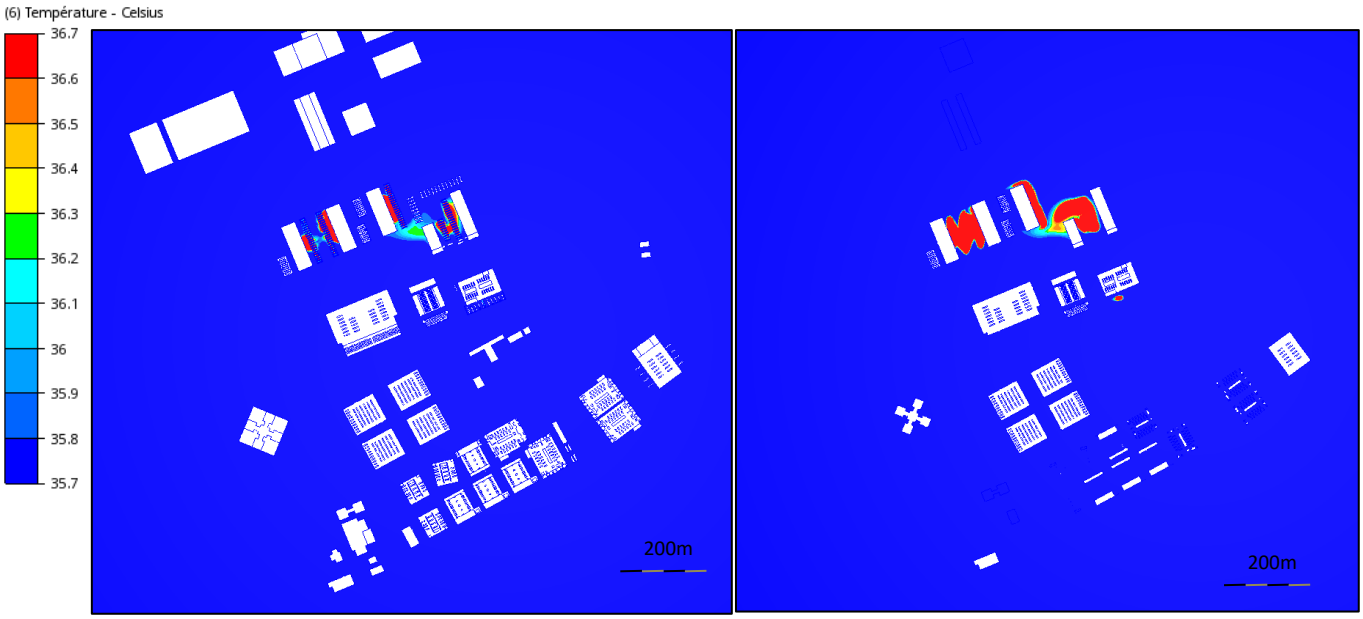


Figure – Temperature plans at 1m and 15m – Equinix campus scenario

The temperature plane at 1 m shows that the chiller and generator exhausts have no impact outside the campus, nor even within the campus except within 10 m of the chillers, with a temperature delta below 0.1°C in all these areas. Only a small green zone, with a temperature delta on the order of 0.5°C, is present between ML11 and ML7 (inside the Equinix campus). At 15 m (i.e. at the top level of the buildings), the high temperatures are also confined to these same areas. Since warm air masses are lighter than ambient air, they rise rapidly in altitude and therefore do not descend again downstream due to their lower density.

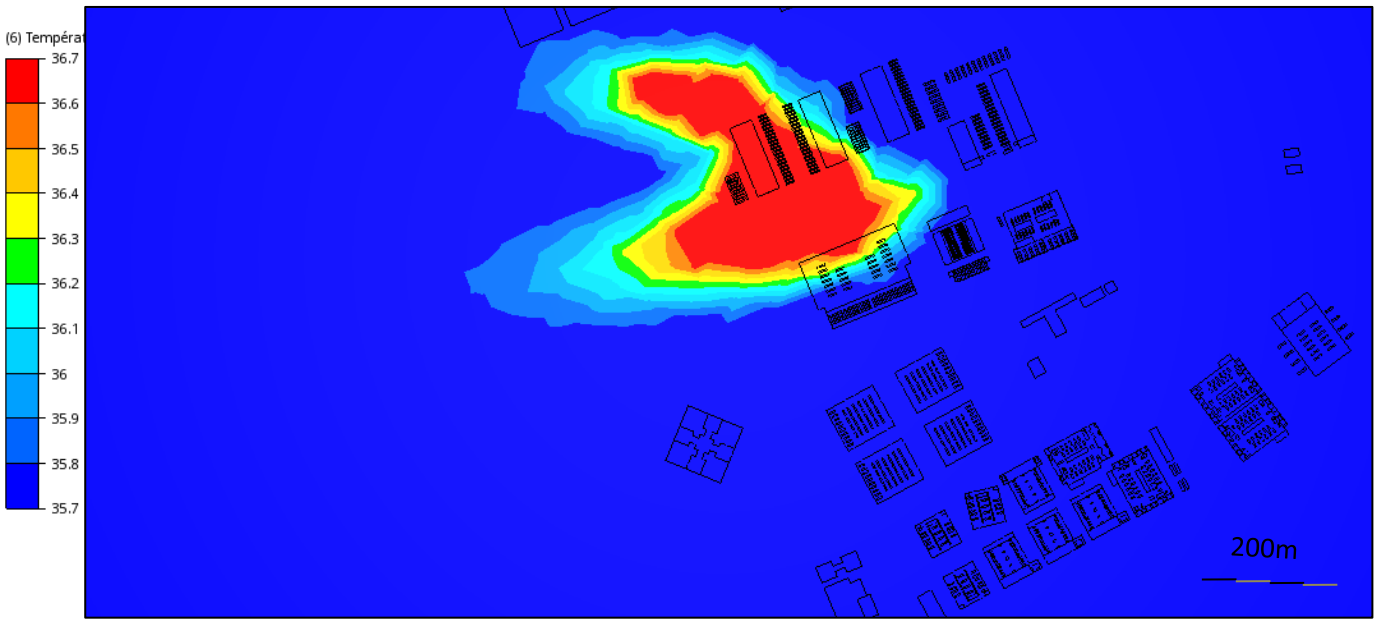


Figure – Temperature plan at 200m – Equinix campus scenario

At 200 m altitude, the warm air masses now extend beyond the campus due to the wind-driven sweeping effect. The thermal emissions from the campus then combine into a single rising warm air mass, which moves in the direction of the wind but remains confined at altitude before gradually dissipating. This warm air mass at altitude does not have a significant impact on ground-level temperatures.

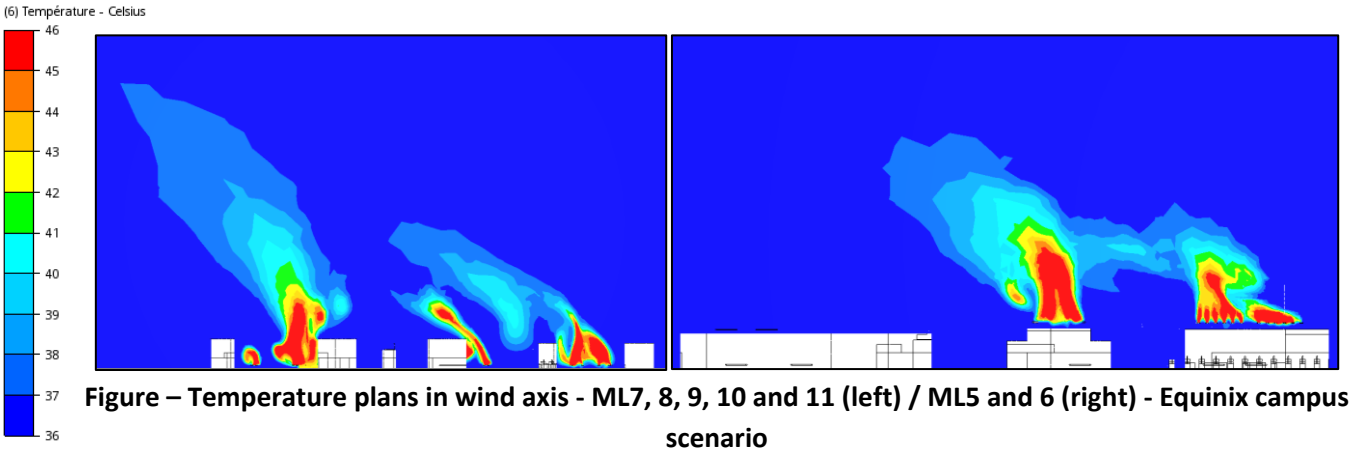


Figure – Temperature plans in wind axis - ML7, 8, 9, 10 and 11 (left) / ML5 and 6 (right) - Equinix campus scenario

These temperature cross-sections along the wind axis illustrate that, despite the lowering of the thermal plumes by the wind, they do not descend back to ground level and dissipate at altitude.

5.2.2 Pressure plans

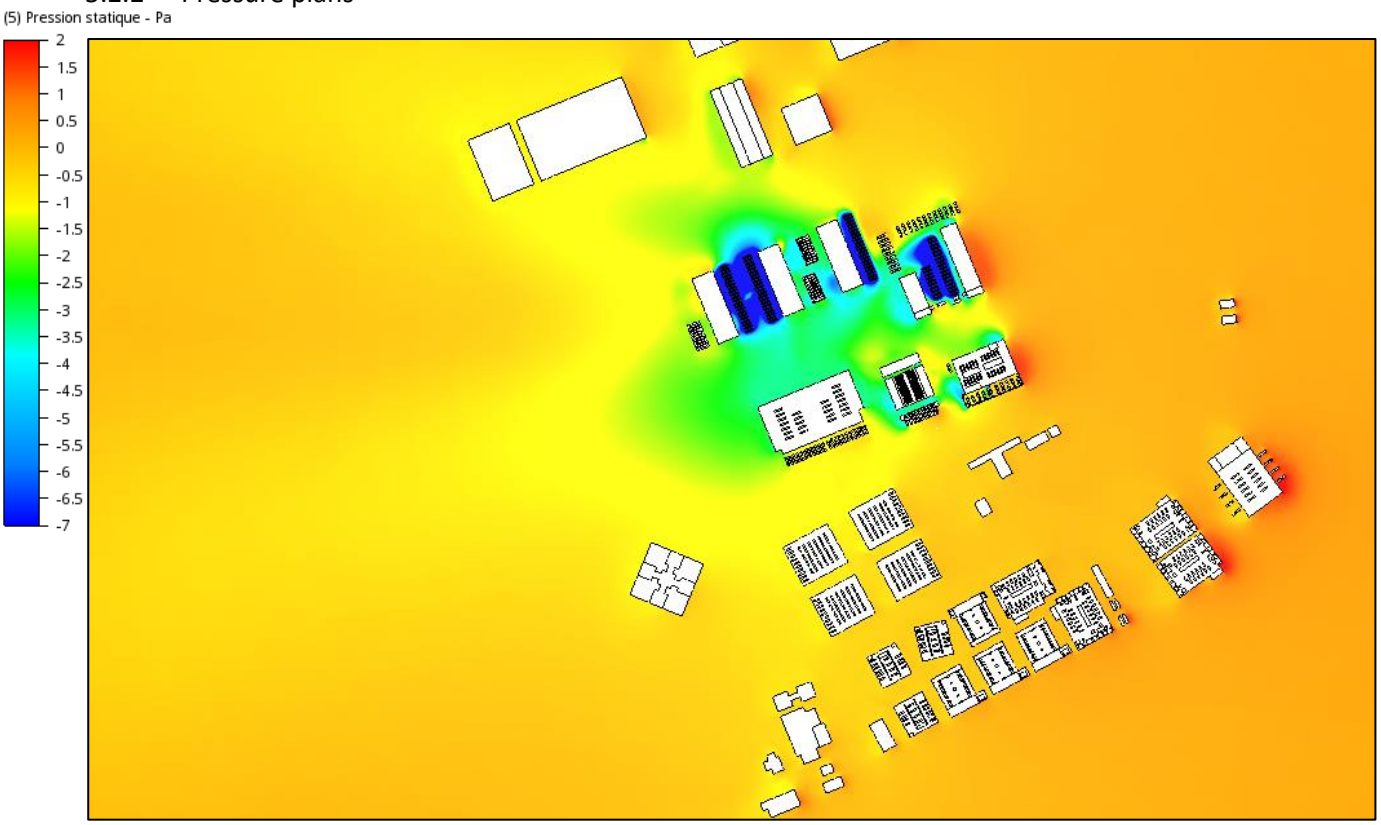


Figure – Pressure plans at 1m - Equinix campus scenario

This pressure map shows that all the suction generated by the chillers and gensets on the campus results in a low-pressure zone of around -3.5 Pa at ground level across the entire Equinix campus, as well as slightly downstream of it. However, this low pressure is not sufficient to re-entrain the warm air masses located at altitude. Pressure drops of around -15 Pa are present directly beneath the chillers.

5.2.3 Temperature isosurfaces

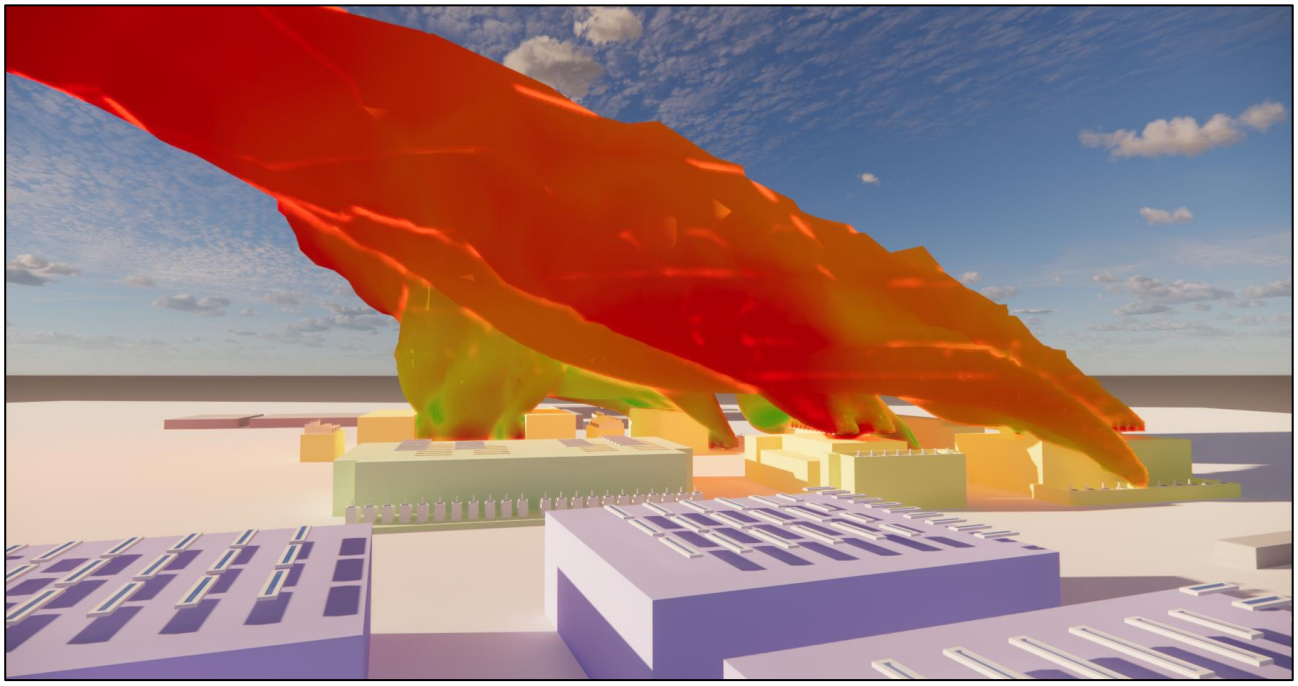


Figure – Temperature isosurface : +1°C - Equinix campus scenario

These isosurfaces illustrate all air masses with a temperature delta greater than 1°C compared to ambient air. It is clearly observed that these air masses tend to rise rapidly in altitude due to the upward orientation of the exhaust flows and the reduction in air density as temperature increases. These plumes then dissipate at altitude, without impacting ground-level temperatures.

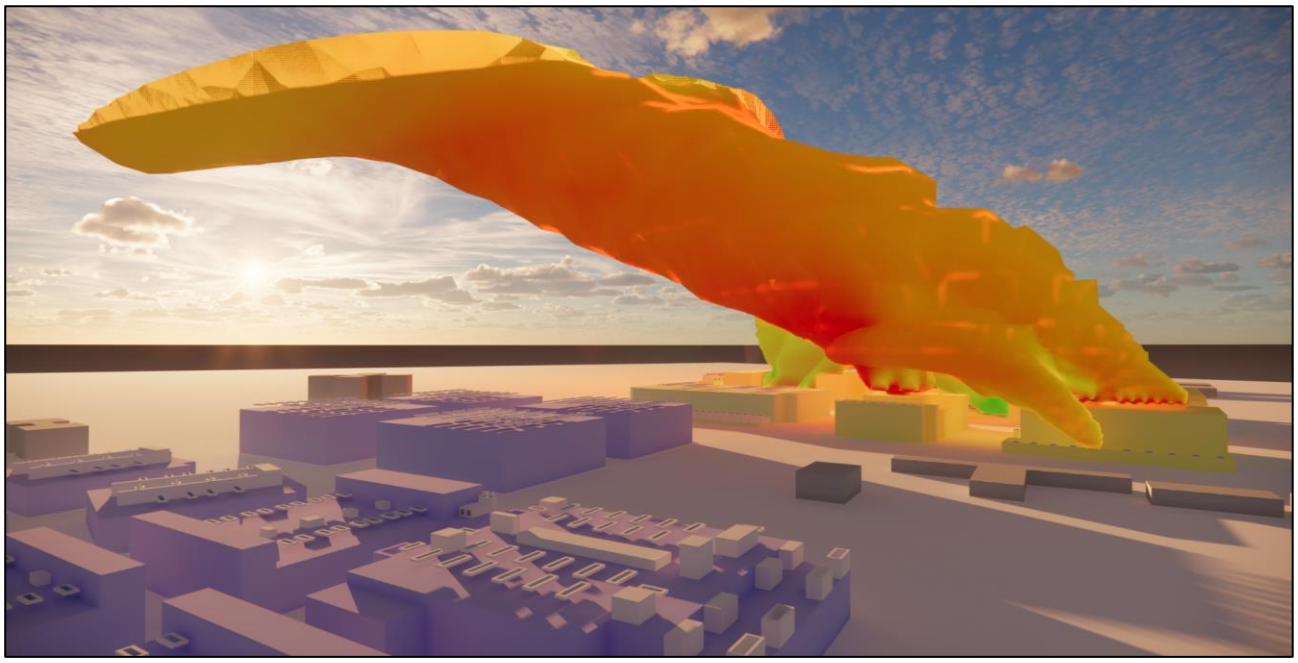
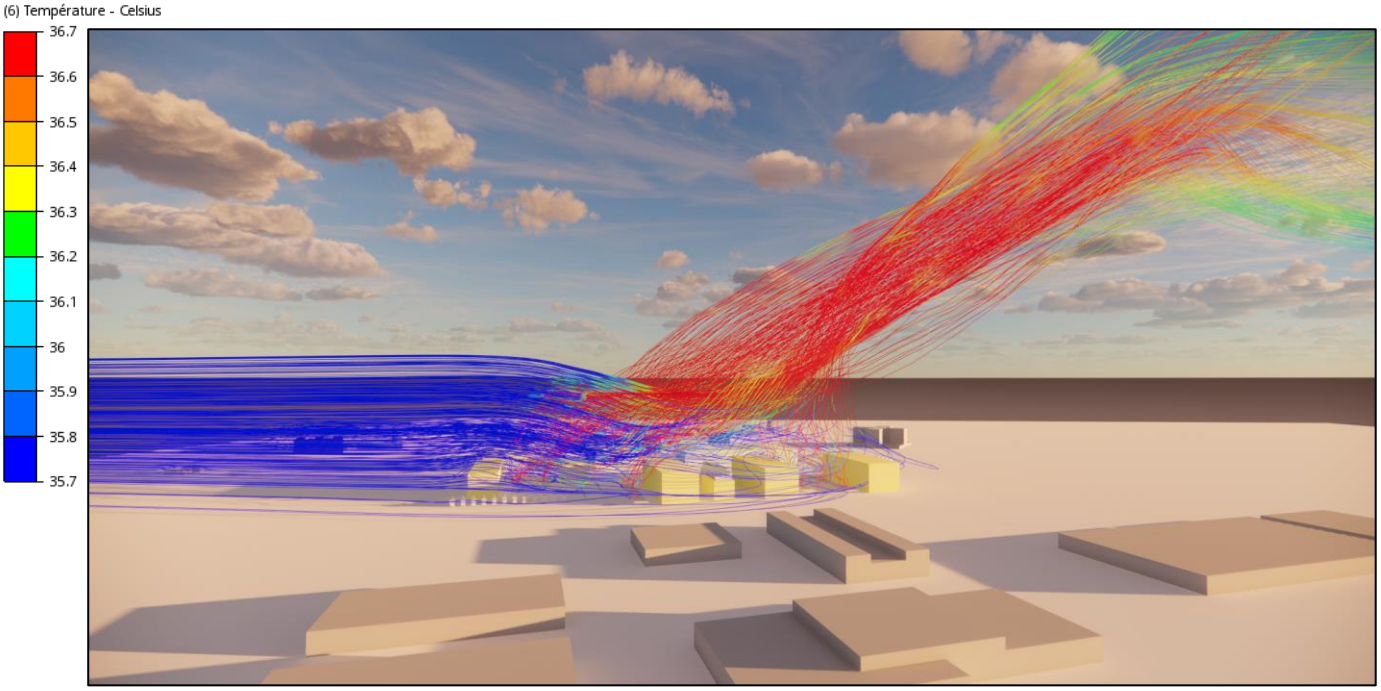


Figure – Temperature isosurface : +0.5°C – Equinix campus scenario

Similarly, this 0.5°C isosurface covers a larger area but remains confined at height and does not impact ground-level temperatures.

5.2.4 Streamlines



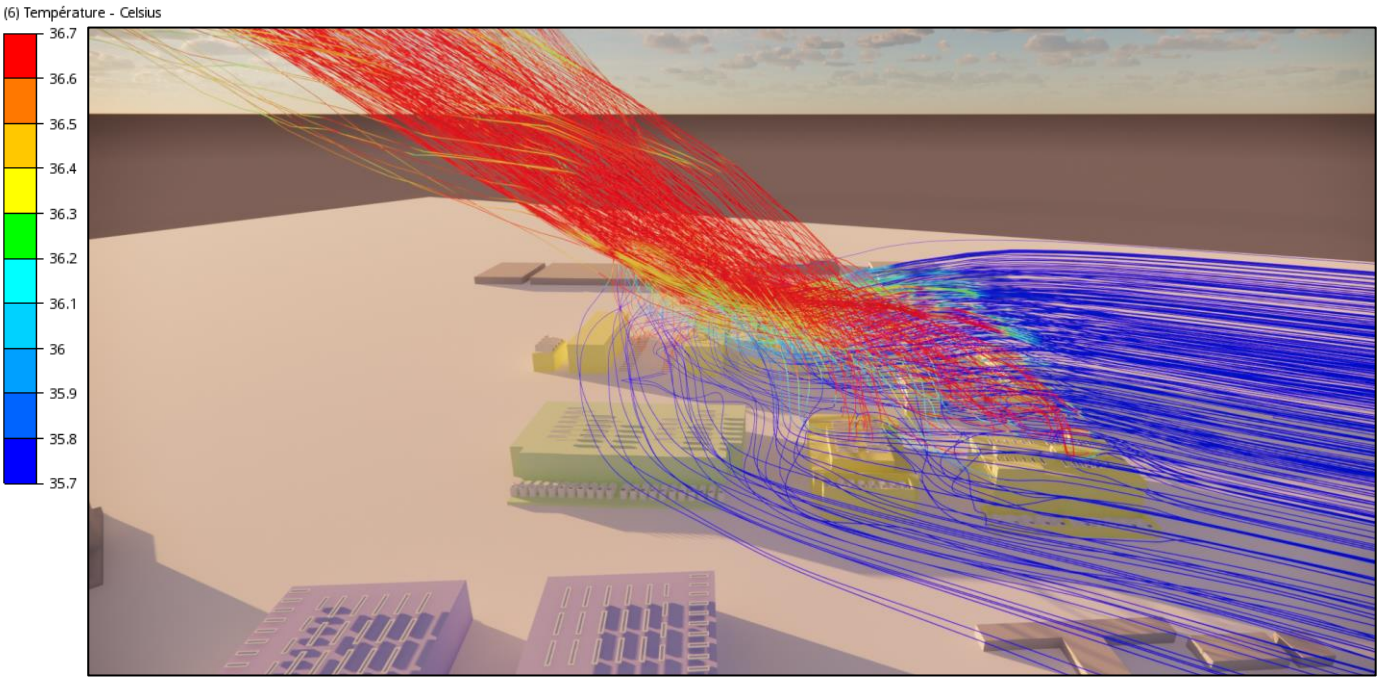


Figure – Streamlines colored by temperature – Hot air at chillers outlet - Equinix campus scenario

These streamlines illustrate the trajectories of air particles passing through the campus. It can then be observed that air masses at ambient temperature enter the campus, pass through heat-emitting systems (chillers, gensets), and increase in temperature while being blown upward by these systems. These air masses, now warmer than the ambient air, continue their upward movement until they cool at high altitude (above 200 m).

5.3. Scenario with all campus

5.3.1 Temperature plans

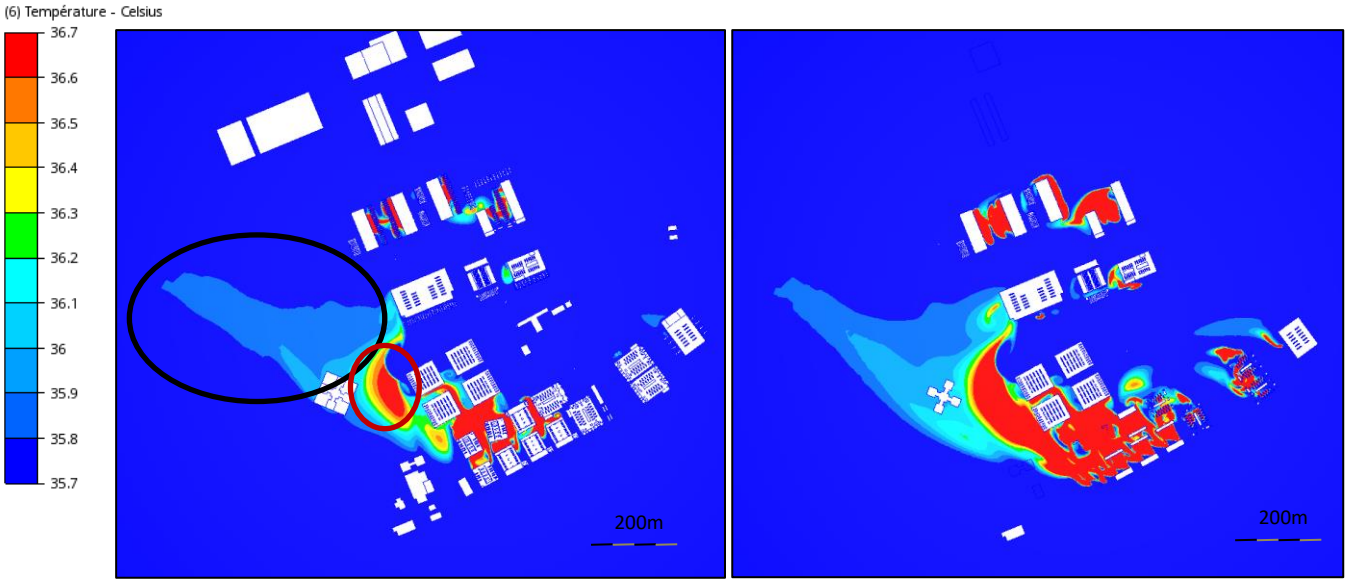


Figure – Temperature plans at 1m and 15m – 4 campuses scenario

Outside the campuses, the increase in ground-level temperature is of the order of more than 1°C over an area of approximately 75 m downstream of buildings DC14 and DC15 (red circle). Then, ground-level temperatures downstream of this area decrease rapidly but remain on the order of 0.1°C over approximately 500 m downstream of these buildings (black circle).

In addition, within the campus, a heat stagnation zone is present at ground level between buildings DC6 and DC14, with a temperature delta greater than 1°C. These two phenomena are due to a high density of buildings and suction at the Data4 campus, creating a significant low-pressure zone at ground level, which then re-entrains part of the warmer air located at higher altitude. Hot spots are also present around the chillers on the Equinix campus at ground level, but only near the chillers and between ML11 and ML7, as in the scenario with the Equinix campus alone.

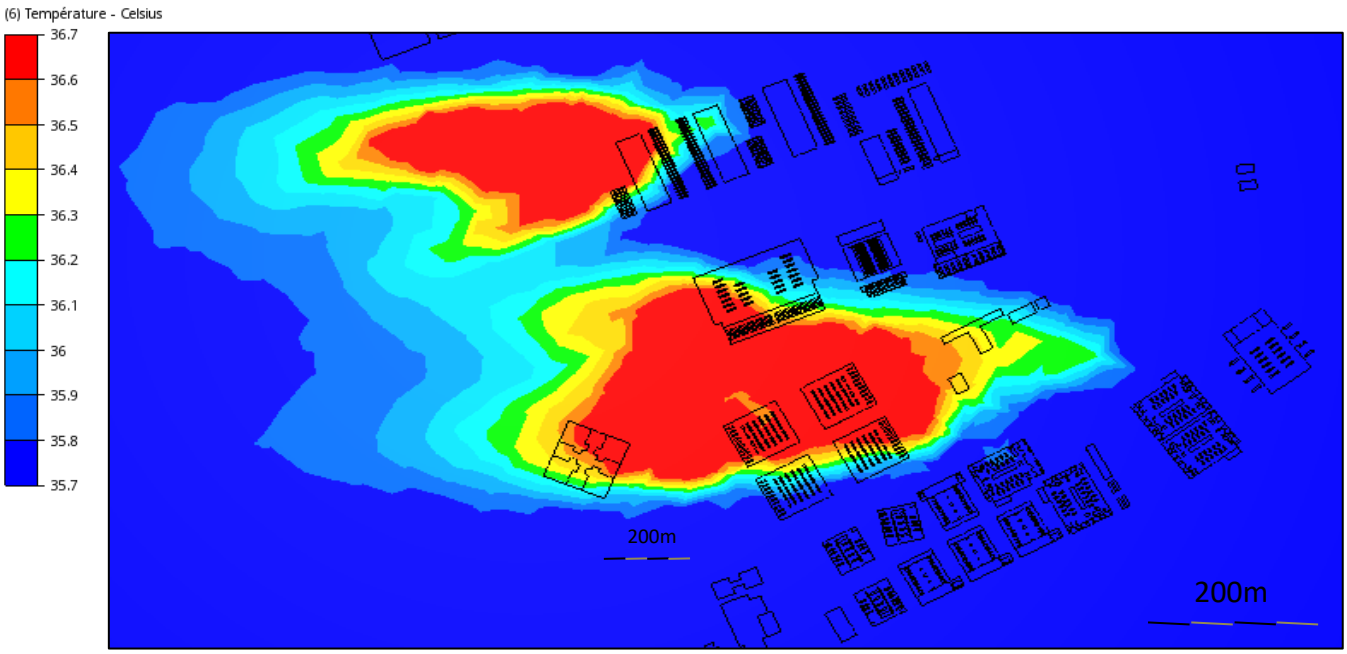


Figure – Temperature plan at 200m – 4 campuses scenario

Similarly to the scenario with only the Equinix campus, at 200 m altitude, the warm air masses now extend significantly beyond the campus due to the wind-driven sweeping effect. The thermal emissions from the campus then combine into two rising warm air masses, which move in the direction of the wind but remain confined at altitude before gradually dissipating. These warm air masses at altitude do not have a significant impact on ground-level temperatures.

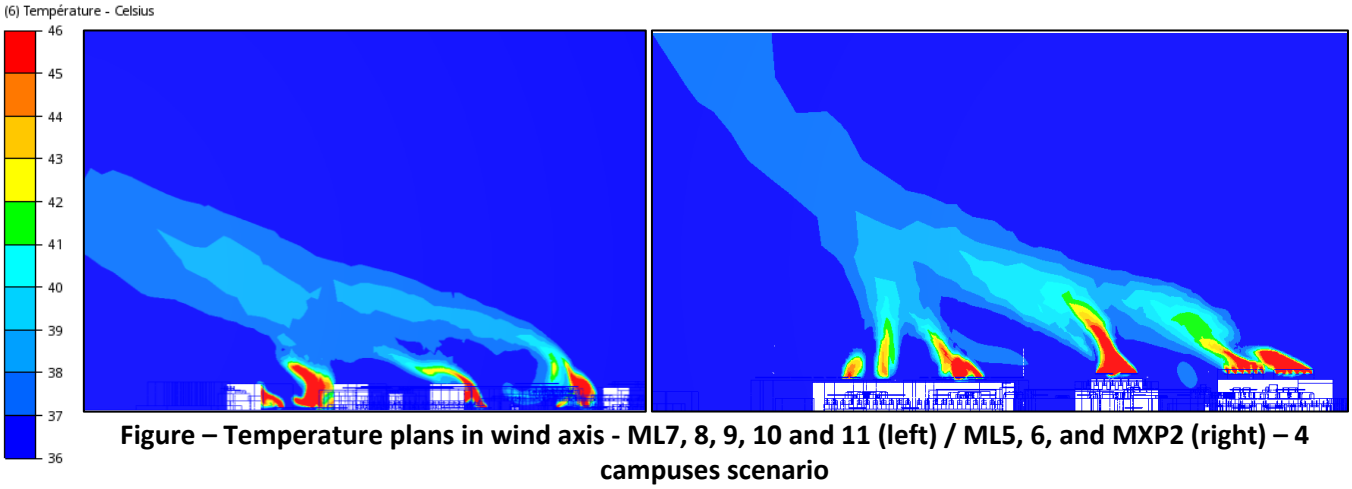


Figure – Temperature plans in wind axis - ML7, 8, 9, 10 and 11 (left) / ML5, 6, and MXP2 (right) – 4 campuses scenario

These temperature cross-sections along the wind axis illustrate that, for the buildings of the Equinix and Vantage campuses, despite the lowering of the thermal plumes by the wind, they do not descend back to ground level and dissipate at altitude.

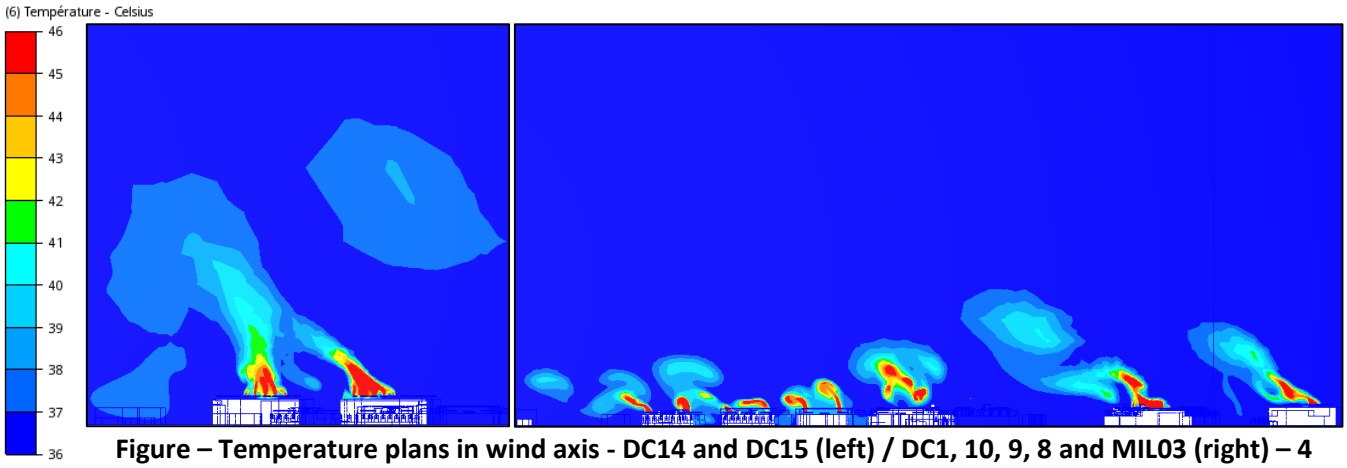


Figure – Temperature plans in wind axis - DC14 and DC15 (left) / DC1, 10, 9, 8 and MIL03 (right) – 4 campuses scenario

These temperature cross-sections along the wind axis illustrate that, for the Equinix campus, the thermal plumes slightly descend at altitude due to the high density of suction at low level and the resulting lack of air generated by it, with temperatures of around +1°C relative to ambient air returning to ground level.

5.3.2 Pressure plans

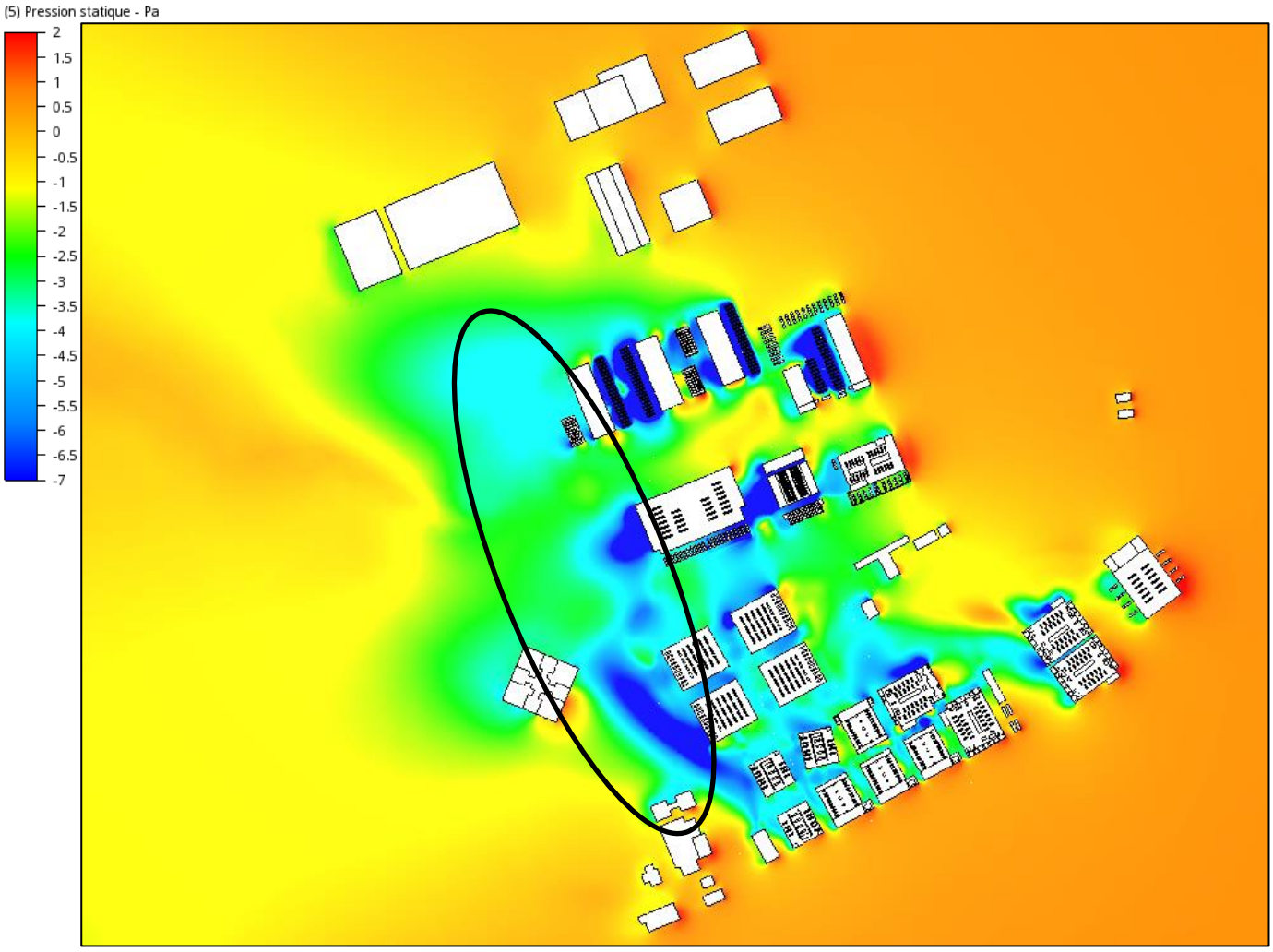


Figure – Pressure plans at 1m - 4 campuses scenario

This pressure map shows a large low-pressure zone downstream of the data center campuses, with pressures ranging from -3 to -7 Pa. This low pressure is generated by the high density of suction within the campus, particularly due to the chillers, and helps promote the re-entrainment of warm air masses located at higher altitude back toward ground level.

5.3.3 Temperature isosurfaces

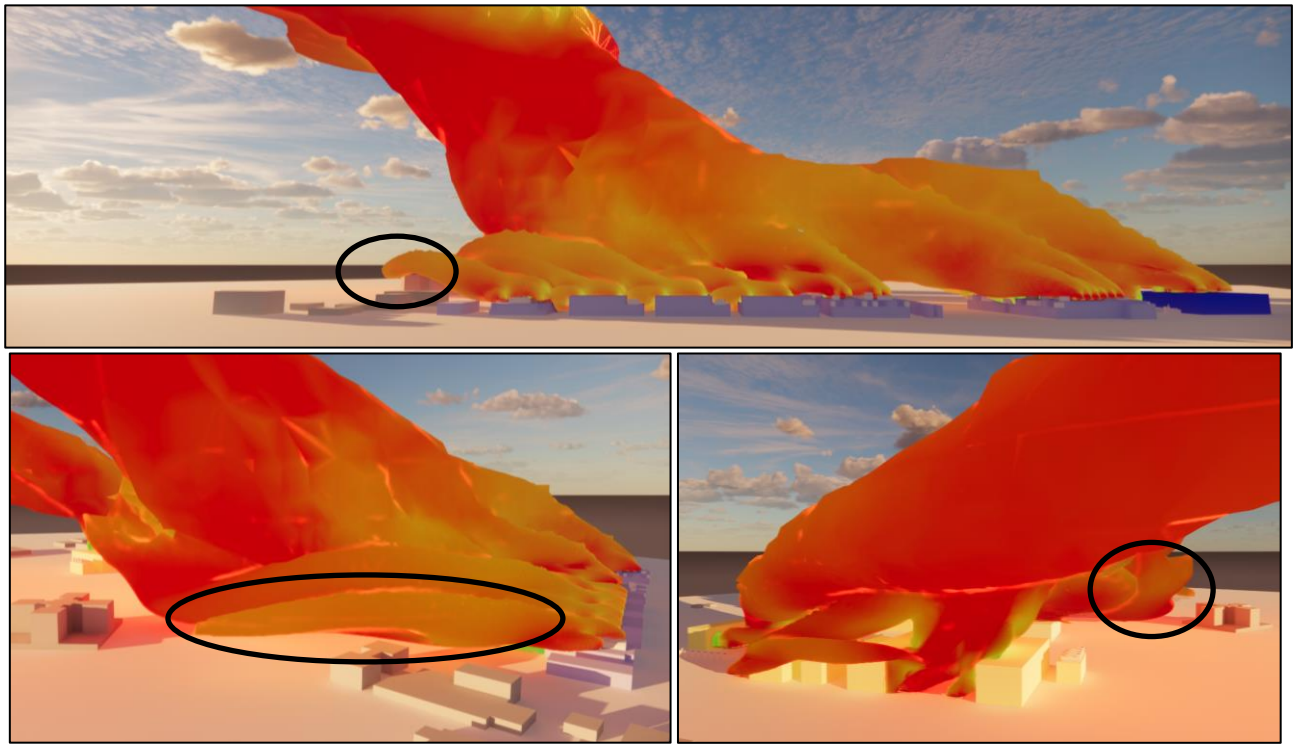


Figure – Temperature isosurface : +1°C - 4 campuses scenario

These figures illustrate all air masses with a temperature delta greater than +1°C compared to ambient air. It can then be observed that, despite a dominant tendency for air blown by the chillers and carrying heat to rise rapidly in altitude, some thermal plumes partially descend to lower levels (black circles). This area where the plumes descend corresponds to the downstream region of the campus where a strong low-pressure zone, on the order of -7 Pa, is present at ground level.

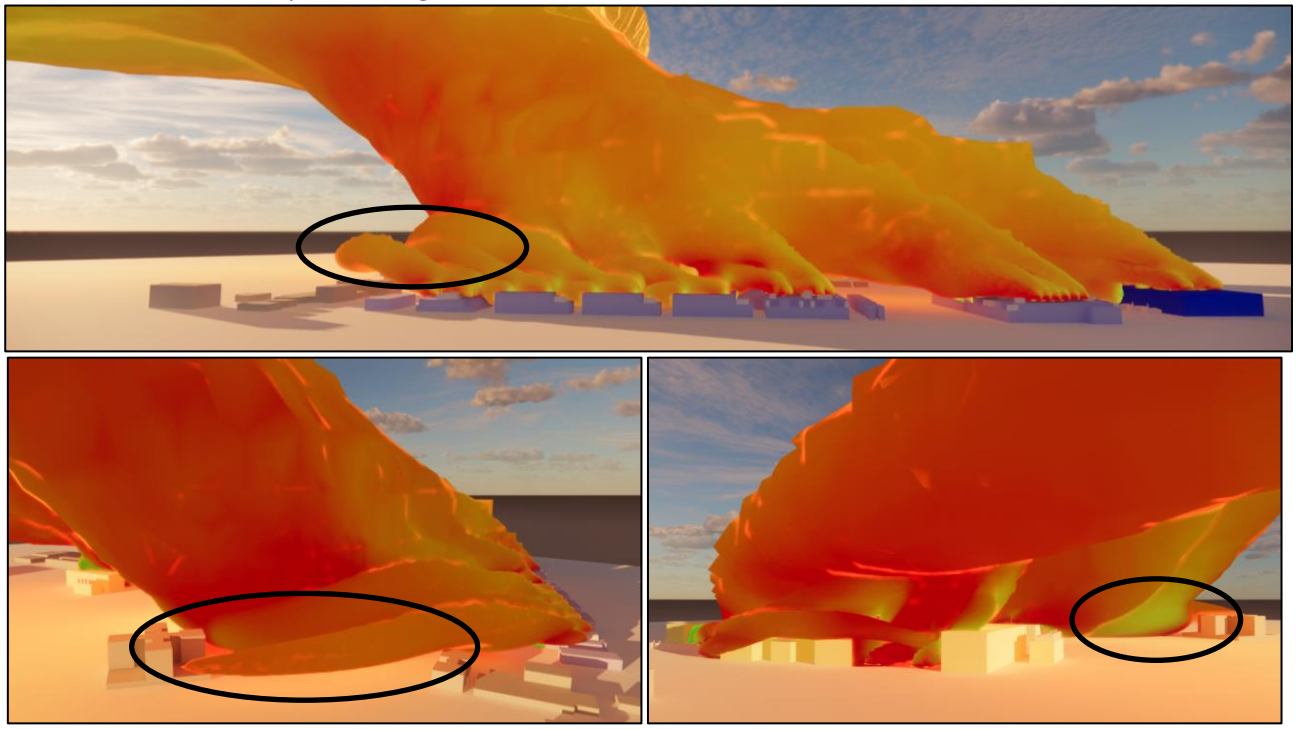


Figure – Temperature isosurface : +0.5°C - 4 campuses scenario

Similarly, an even larger mass of air with a temperature more than 0.5°C above ambient temperature comes into contact with the ground and increases local temperatures within the low-pressure zone.

5.3.4 Streamlines

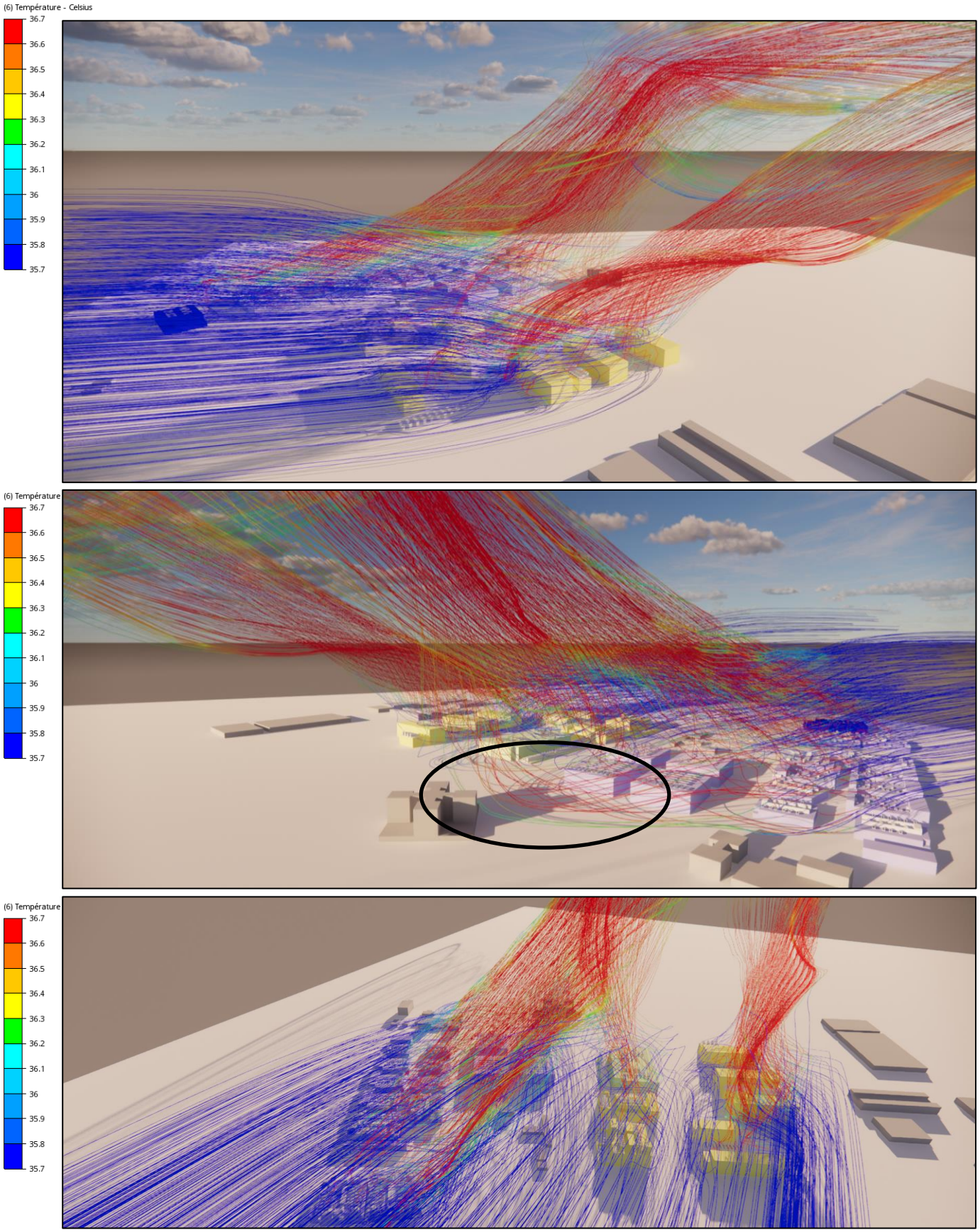
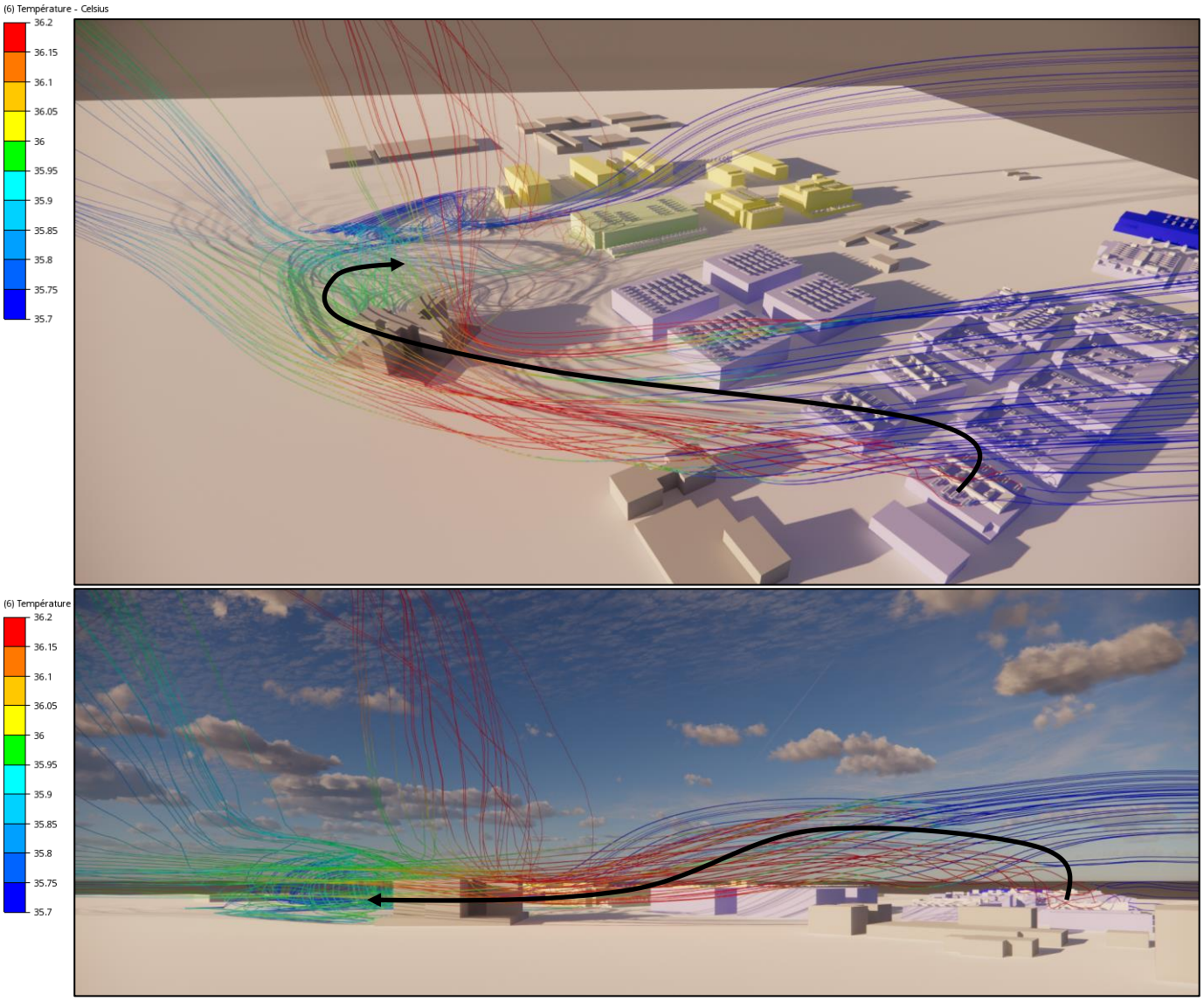


Figure – Streamlines colored by temperature – Hot air at chillers outlet - 4 campuses scenario

Similarly to the isosurfaces, these streamlines illustrate that, despite an overall tendency for the air passing through the campus to warm up and rise rapidly in altitude, part of the streamlines—particularly those coming from DC1, DC2, DC3, and DC4—descend back to ground level downstream of the campus before rising again, thereby increasing local temperatures by around 1°C.



Figures – Streamlines colored by temperature – Area where calories accumulate downstream of the campus – 4 campuses scenario

These streamlines illustrate only the air masses passing through the chillers of DC1, which then heat up but are partially re-entrained at low level downstream of the campus due to the significant low pressure generated by the high density of suction systems (chillers, gensets). This results in temperatures of around +0.3 to +0.5°C relative to ambient conditions at the neighboring building level.

5.4. Generalisation to all wind directions

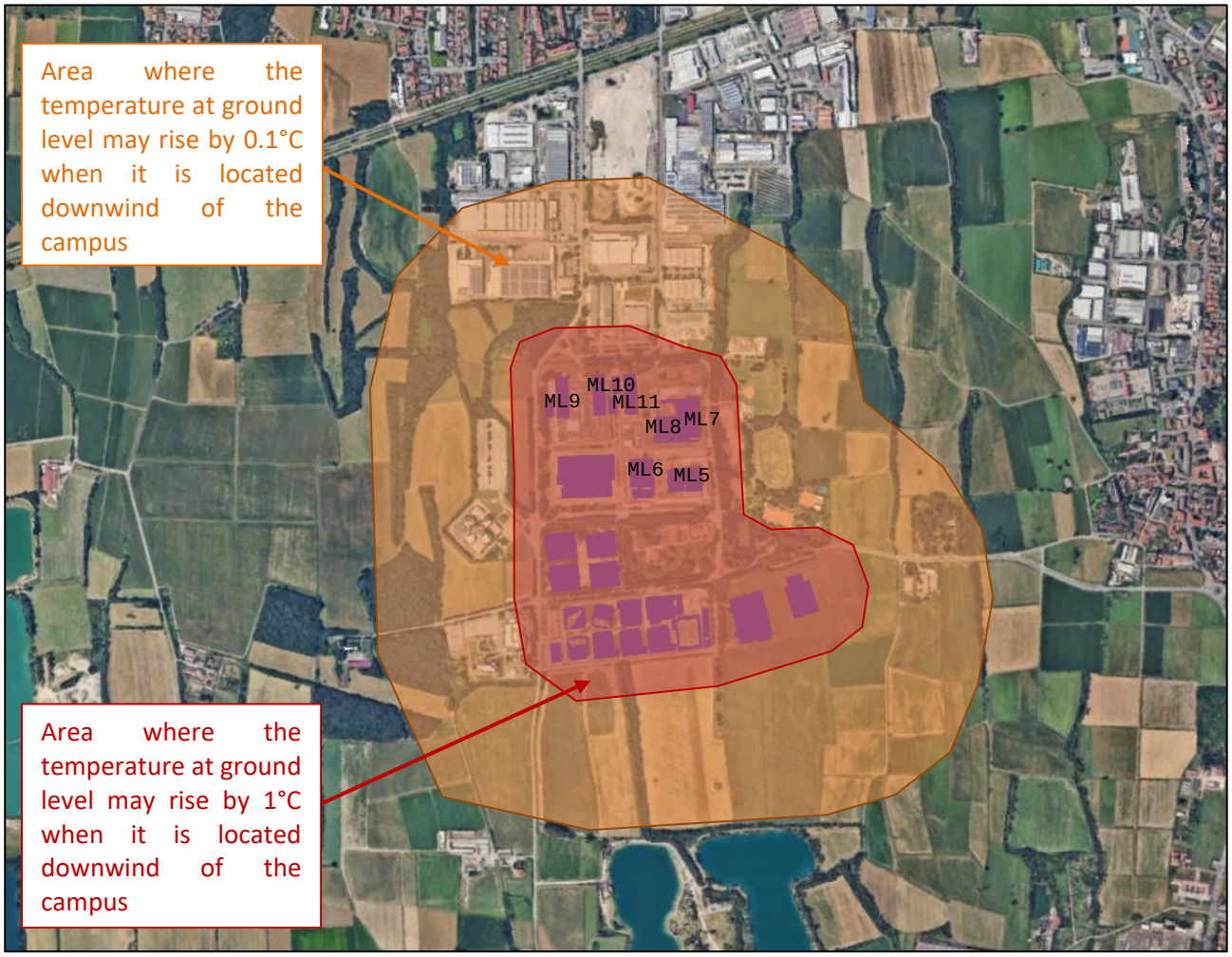


Figure – Extension of areas of potential temperature rise to all wind directions – 4 campuses scenario

A generalization of the study results was carried out for all possible wind directions, namely a local increase in ground-level temperatures of around 0.1°C over approximately 500 m downstream of the campus, and a local increase in ground-level temperatures of around 1°C over approximately 75 m downstream of the campus. Thus, zones with a potential temperature increase depending on wind direction of 0.1°C and 1°C were mapped using these distances around the campus.

6. Overall conclusion of the studies

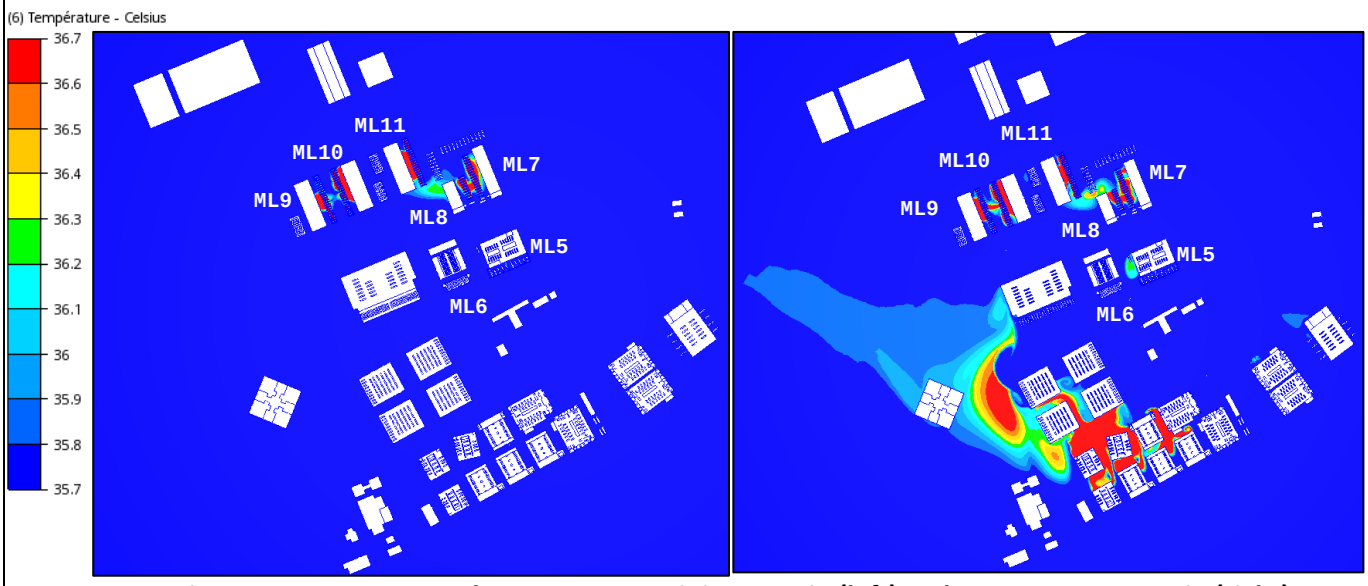
The CFD study carried out on the different operating scenarios of the data center campuses highlights the overall behaviour of the thermal emissions generated by the chillers and generator sets under summer weather conditions (outdoor temperature of 35.7°C and wind speed of 2.0 m/s coming from the East).

- In the initial scenario, without considering the data center installations, no temperature increase is observed and pressure variations remain very low, with no significant influence on airflow.

- The analysis of the scenario including only the Equinix campus shows that the thermal plumes produced by the equipment remain mostly confined within the site and rise rapidly in altitude due to the combined effect of vertical exhaust flows and thermal buoyancy. Impacts at ground level and on nearby buildings remain very limited, with temperature increases below 0.1°C outside the immediate vicinity of the chillers. Areas with higher temperatures remain localized within the campus and do not generate any significant recirculation phenomenon.

- The scenario including all four campuses nevertheless highlights more pronounced aerodynamic interactions linked to the high density of suction systems and buildings. A significant low-pressure zone then forms downstream of the installations, locally promoting the re-entrainment toward ground level of part of the warm air masses present at altitude. This phenomenon leads to localized temperature increases of up to approximately +1°C over a distance of around 75 m downstream of the campus, as well as lower increases on the order of +0.1°C up to approximately 500 m downwind. However, these effects remain confined to limited areas mainly located downstream of the DATA4 campus and do not challenge the overall upward behaviour of the thermal plumes.

The 1 m ground-level temperature maps for the scenarios with only the Equinix campus, and then with all four campuses, are shown below (the case without any campus being at ambient temperature everywhere):



Figures – Temperature plans at 1m – Equinix scenario (left) and 4 campuses scenario (right)

Furthermore, the increase in negative pressure at 1.5 metres caused by the high suction rate of the chillers—which facilitates the re-entry of warm air masses into the lower part of the building—is illustrated in the pressure diagrams below. It should be noted that the pressure is particularly lower downstream of the buildings due to the wind. It should also be noted that the increase in negative pressure when the four campuses are taken into account slightly favours the descent of air masses in the lower part of the Equinix campus as well (on a very small scale).

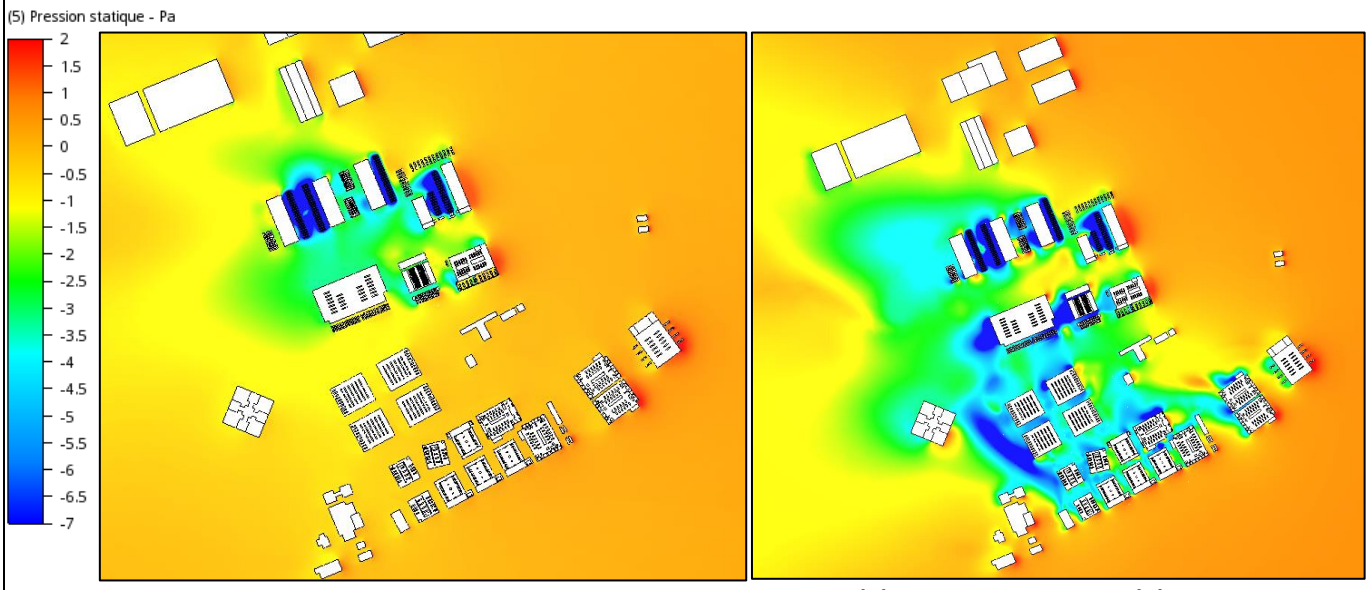


Figure – Pressure plan at 1m50 – Equinix only (1) and all 4 campuses (2)

The temperature isosurfaces and streamlines confirm that the dominant dynamic of the thermal emissions remains a rapid rise at altitude of the heated air masses followed by a gradual dissipation at altitude. The observed ground-level recirculation phenomena remain localized and are directly linked to areas of strong low pressure induced by the concentration of suction. The isosurfaces and streamlines below illustrate this upward trend of warm air masses leaving the chillers:

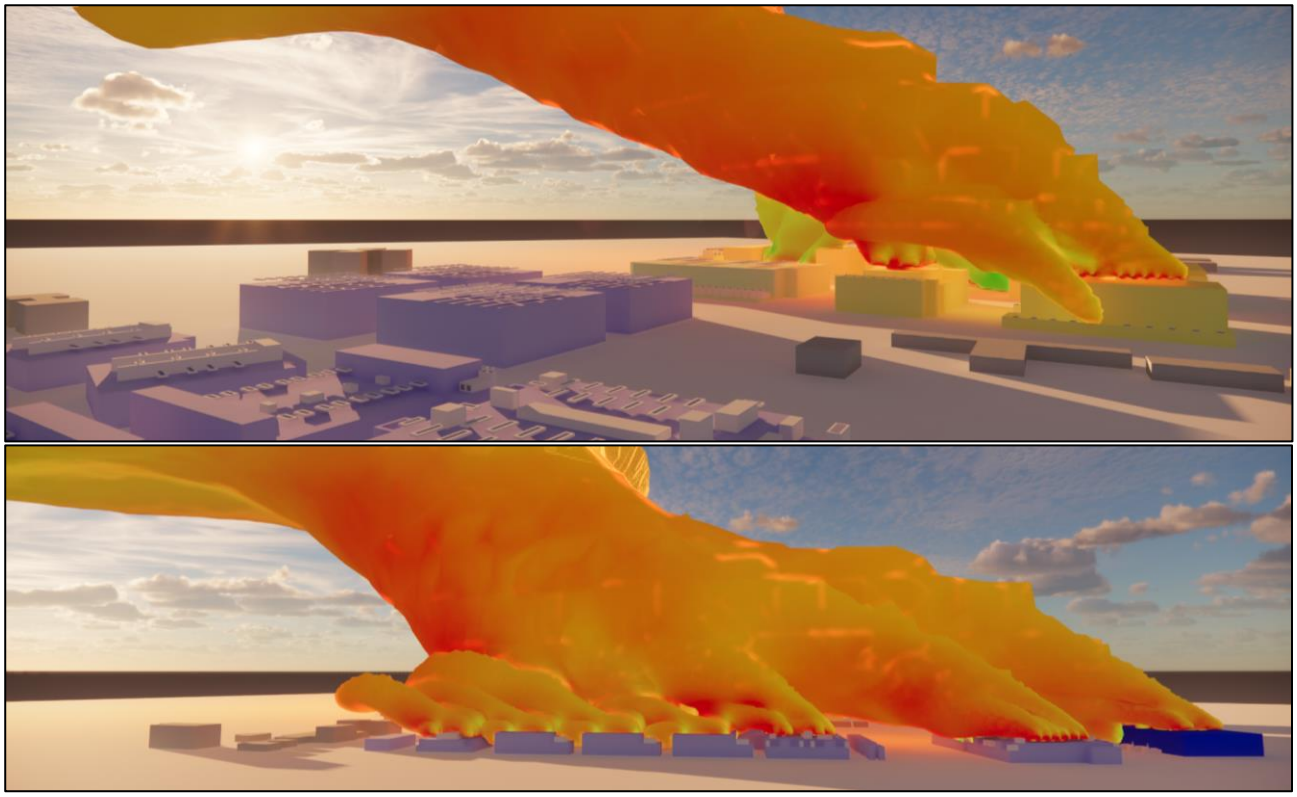


Figure – Temperature isosurface of +0.5°C – Equinix only (1) and 4 campuses (2)

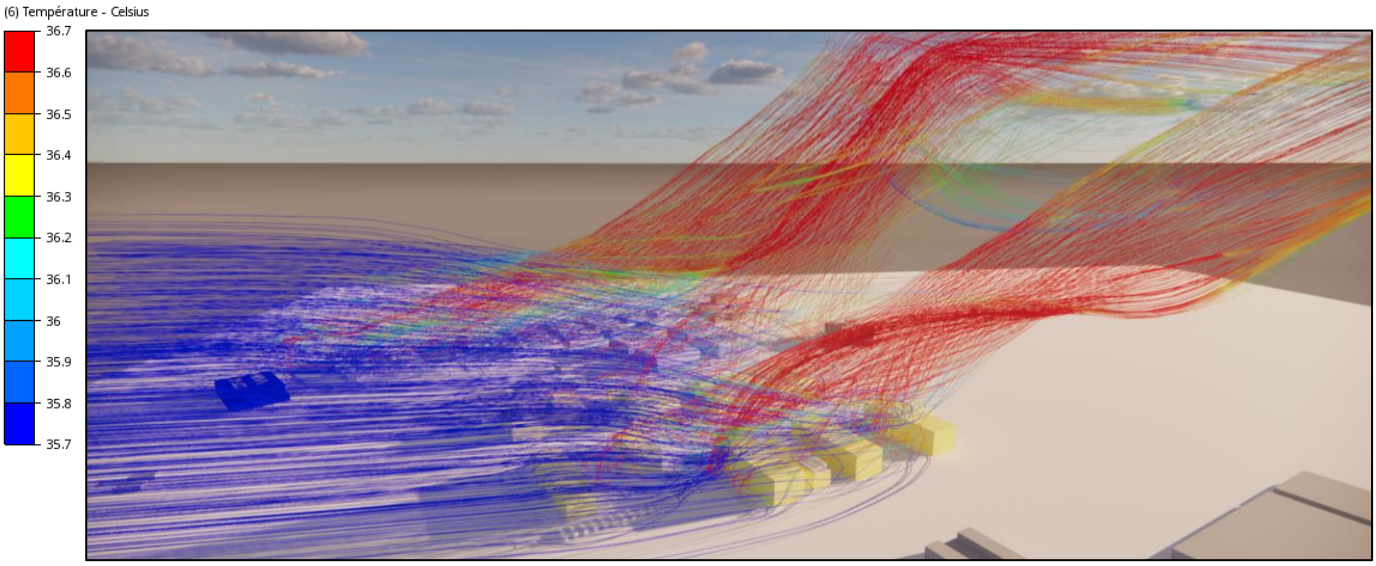


Figure – Streamlines colored by temperature – 4 campuses scenario

Finally, generalizing the results to all wind directions makes it possible to identify potential zones of local temperature increase around the campuses for different levels of thermal impact. This approach provides an overall view of the sensitive areas likely to be affected by local warming effects depending on wind direction, as illustrated below. Temperature increases are not simultaneously present across the entire area enclosed by the isotherms. Heat emissions are transported by the wind and mainly affect the area located downstream of the campus relative to the prevailing wind direction, and so heat zone vary with the wind :

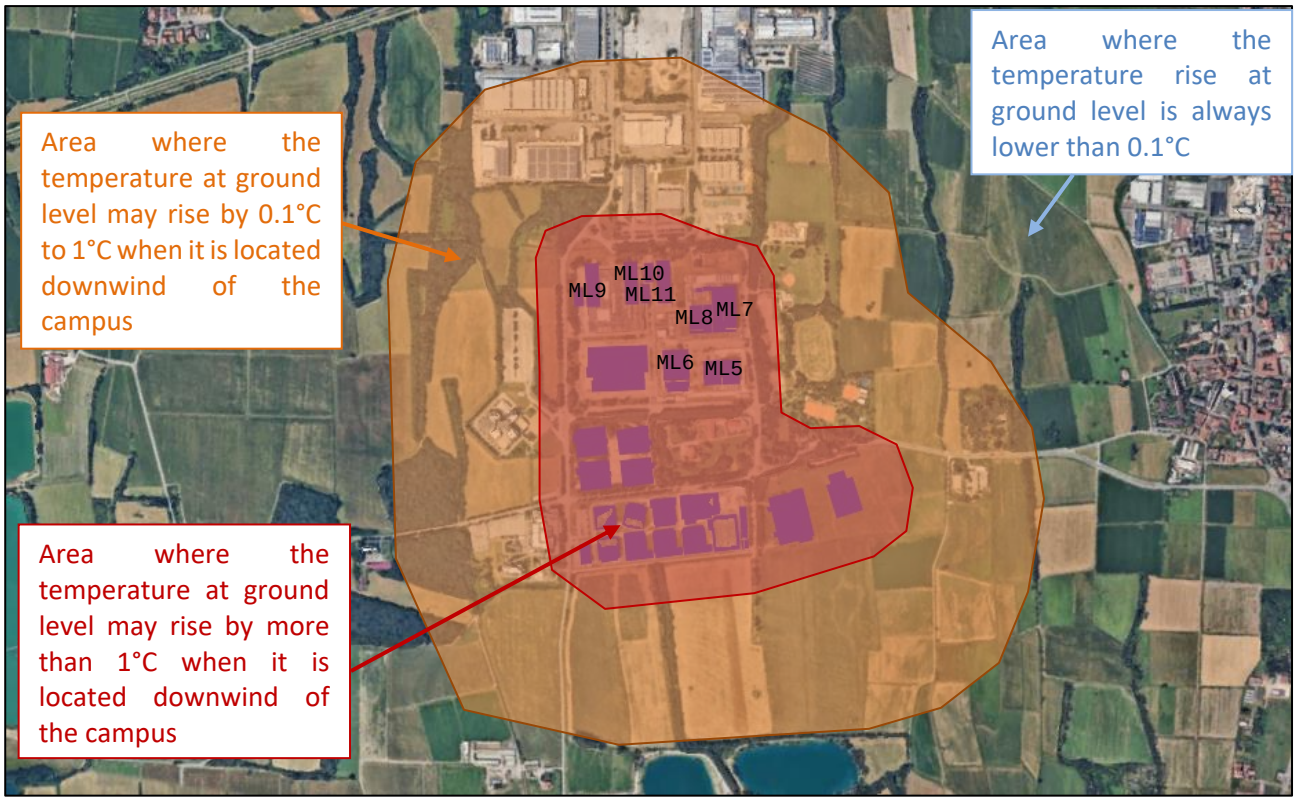


Figure - Extension of areas with potential for temperature increases to all wind directions

7. Annex A – System Data Sheets

7.1. Equinix buildings data set

7.1.1 Chillers ML5

1. Equipment performance schedule

Model: NSG3402XB°A°J°PG

Code	NSG
Size	3402
Working fields	X - Electronic thermostatic valve (outlet water temperature from +4 °C)
Model	B - Free-Cooling (glycol free)
Heat recovery	° - Without heat recovery
Version	A - High efficiency
Coils	° - Aluminium (microchannel)
Fans	J - Inverter
Power supply	° - 400V/3/50Hz with fuses
Hydronic kit	PG - Type G

Cooling

Selection data @ design

Capacity	kW	887.4
Input power	kW	261.4
Input current	A	424
EER	W/W	3.39
Height above sea level	m	0
Dry bulb air inlet temperature	°C	38.6
Inlet water temperature	°C	32.0
Outlet water temperature	°C	20.0
Temperature difference	°C	12.0
Ethylene glycol	%	0
Water flow rate	l/s	17.74
Available pressure	kPa	230
Fouling factor	(m² K)/W	0

Selection data @ 45C

Capacity (86% of total at 38.6C)	kW	763
Input power	kW	252.9
EER	W/W	3.00
Dry bulb air inlet temperature	°C	45.0

Performance at AHRI550/590 condition

Capacity	kW	595.7
Input power	kW	212
Input current	A	351
EER	W/W	2.81
IPLV	W/W	3.85

General data

Refrigerant circuit data

Refrigerant			R1234ze
Driver			Modulation with slide valve
Compressor type			Screw
Number of compressors		n.	2
Number of cooling circuits		n.	2
Oil charge	C1	l	4.14
	C2	l	30
Refrigerant charge		kg	117
Refrigerant charge - Eurovent conditions		kg/kW	0.188
Refrigerant charge – AHRI conditions		Kg/kW	0.196

Fan group data (nominal data)

Driver		Inverter
Fan type		Axial
Number of fans	n.	14
Air flow rate	m³/s	65.54472

Water circuit data

Exchanger type		Shell and tube
Number of exchangers	n.	1
Expansion tank number	n.	2
Expansion tank capacity	l	25

Sound data

Sound power - Lw	dB(A)	99.4
Sound pressure at 10 m	dB(A)	66.6

Sound spectrum for octave bands (center frequency)

	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
Lw - dB	95.8	93.6	94.8	95.4	93.1	86.7	78.1
Lw - dB(A)	79.7	85.0	91.6	95.4	94.3	87.7	77.0

The sound levels are given at full load, without pumps (if available) and at nominal conditions (air temperature: 35.0 °C, water temperature (in/out): 12.0/7.0 °C).

Electric data

Full Load Amps (FLA)	A	532.23
Locked Rotor Amps (LRA)	A	699.13
Power supply		400V/3/50Hz with fuses

Figure – Chillers technical datasheet – ML5

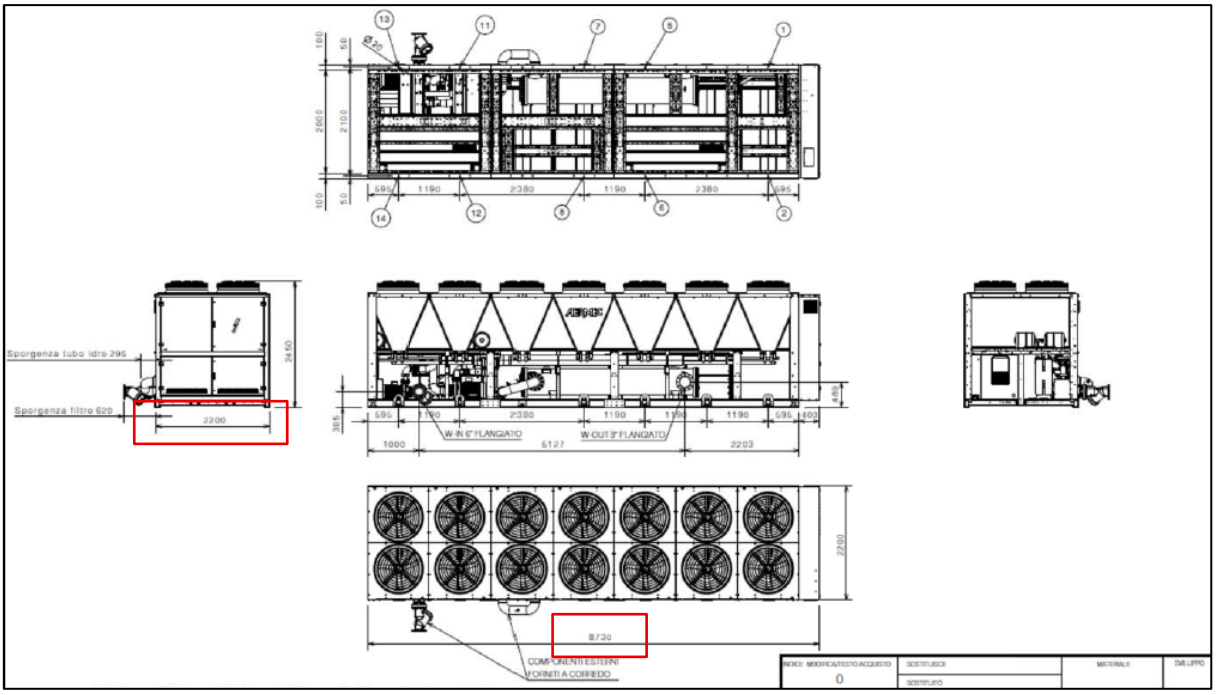


Figure – Chillers technical drawing – ML5

7.1.2 Chillers ML6-11

Cooling

Selection data – without pump

Capacity	kW	1473.9
Input power	kW	349.7
Input current	A	569
EER	W/W	4.21
Dry bulb air inlet temperature	°C	39
Inlet water temperature	°C	28.0
Outlet water temperature	°C	22.0
Temperature difference	°C	6.0
Propylene glycol (primary circuit)	%	0
Water flow rate	l/h	211265
Pressure drops	kPa	123
Fouling factor	(m² K)/W	0
Fan external resistance	Pa	0

Selection data – with INTEGRAL "KJ" pump

Capacity	kW	1473.9
Input power	kW	386.7
Input current	A	636
EER	W/W	3.81
Dry bulb air inlet temperature	°C	39
Inlet water temperature	°C	28.0
Outlet water temperature	°C	22.0
Temperature difference	°C	6.0
Propylene glycol (primary circuit)	%	0
Water flow rate	l/h	211265
Available static pressure	kPa	275
Fouling factor	(m² K)/W	0
Fan external resistance	Pa	0
Pump		Twin -head pump duty sharing

Note, the chiller is supplied WITH integral twin head pump duty sharing. The data is split to indicate the additional input power for the pump which has its own separate power supply.

General data

Cooling mode for low temperature

ηsc		206.10
SEER		5.23

Refrigerant circuit data

Refrigerant		R513A
Driver		Inverter modulation
Compressor type		Centrifugal
Number of compressors	n.	3
Number of cooling circuits	n.	1
Refrigerant gas charge	kg	400

Fan group data

Driver		Inverter modulation
Fan type		Axial
Number of fans	n.	22
Air flow rate	m³/s	115
Available airside static pressure (*)	Pa	0

*The fans have the ability to overcome an additional airside pressure drop of upto 50Pa at increased input power.

Water circuit data

Exchanger type		Shell and tube
Number of exchangers	n.	1
Water content	l	336
Connections type		PN16 Flanged
Water connections of exchanger	inlet	6"
	outlet	6"

Sound data (nominal cooling data)

Sound power (Tair <=38°C)	dB(A)	97
Sound power (Tair >38°C)	dB(A)	99

Electric data (with compressors limited @ 157A and without pump on primary side)

Full Load Amps (FLA)	A	575.00
Locked Rotor Amps (LRA)	A	430.00
Power factor at full load	cos(θ)	0.89
Total harmonic distortion		34-35%
Power supply		400/V/3/50Hz with fuses
Power supply – chiller mains		2x 400/3/50 to ATS
Power supply – pump		2x 400/3/50 to ATS
Power supply – controls		Off pump supply with integral Supercapacitor
Harmonic shunt filter connections (filter by others)		400/3/50 with fuses (terminals only)

Figure – Chillers technical datasheet - ML6 to ML11

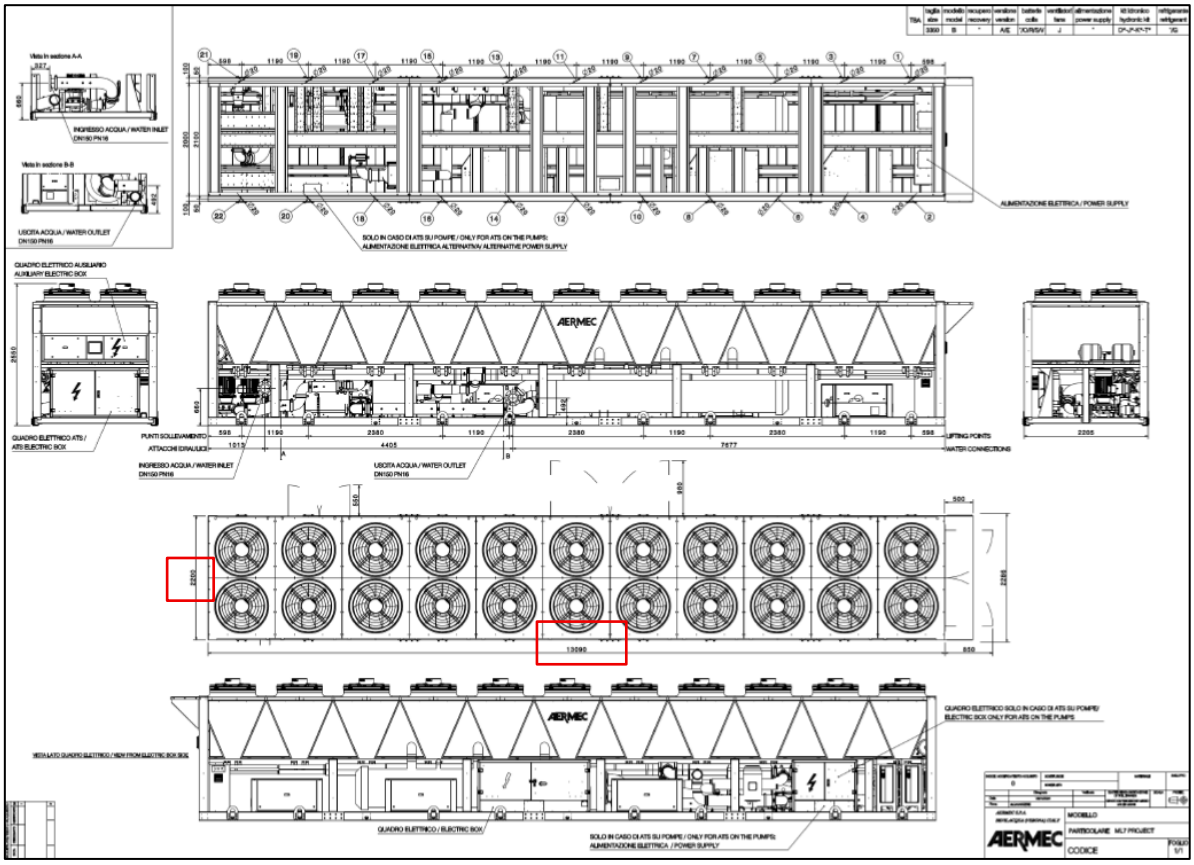


Figure – Chillers technical drawing - ML6 to ML11

The data from this technical datasheet were also used for the chillers of ML6, as the latest design drawings show 13 m-long chillers. They were therefore assumed to be identical to those used in buildings ML7 to ML11, which was subsequently validated with the client.

7.1.3 ML5 Generators

Package Performance

Performance	Standby		Mission Critical		Prime	
Frequency	50 Hz		50 Hz		50 Hz	
Gen set power rating with fan	2400 ekW		2400 ekW		2200 ekW	
Gen set power rating with fan @ 0.8 power factor	3000 kVA		3000 kVA		2750 kVA	
Emissions	Low Fuel		Low Fuel		Low Fuel	
Performance number	EM1314-00		EM1316-00		EM1722-01	
Fuel Consumption						
100% load with fan – L/hr (gal/hr)	614.6	(162.4)	614.6	(162.4)	563.8	(148.9)
75% load with fan – L/hr (gal/hr)	466.7	(123.3)	466.7	(123.3)	431.8	(114.1)
50% load with fan – L/hr (gal/hr)	330.6	(87.3)	330.6	(87.3)	309.0	(81.6)
25% load with fan – L/hr (gal/hr)	196.4	(51.9)	196.4	(51.9)	184.4	(48.7)
Cooling System						
Radiator air flow restriction (system) – kPa (in. water)	0.12	(0.48)	0.12	(0.48)	0.12	(0.48)
Radiator air flow – m³/min (cfm)	2534	(89487)	2534	(89487)	2534	(89487)
Engine coolant capacity – L (gal)	233.0	(61.6)	233.0	(61.6)	233.0	(61.6)
Radiator coolant capacity – L (gal)	266	(69.0)	266	(69.0)	266	(69.0)
Total coolant capacity – L (gal)	499	(130.6)	499	(130.6)	499	(130.6)
Inlet Air						
Combustion air inlet flow rate – m³/min (cfm)	195.3	(6897.4)	195.3	(6897.4)	176.8	(6243.8)
Exhaust System						
Exhaust stack gas temperature – °C (°F)	484.7	(904.5)	484.7	(904.5)	484.7	(904.5)
Exhaust gas flow rate – m³/min (cfm)	513.5	(18132.2)	513.5	(18132.2)	469.4	(16576.4)
Exhaust system backpressure (maximum allowable) – kPa (in. water)	6.7	(27.0)	6.7	(27.0)	6.7	(27.0)
Heat Rejection						
Heat rejection to jacket water – kW (Btu/min)	1010	(57430)	1010	(57430)	959	(54562)
Heat rejection to exhaust (total) – kW (Btu/min)	2315	(131673)	2315	(131673)	2140	(121675)
Heat rejection to aftercooler – kW (Btu/min)	640	(36410)	640	(36410)	513	(29156)
Heat rejection to atmosphere from engine – kW (Btu/min)	158	(8968)	158	(8968)	154	(8752)
Heat rejection from alternator – kW (Btu/min)	104	(5920)	104	(5920)	92	(5232)
Emissions (Nominal)						
NOx mg/Nm³ (g/hp-h)	3581.7	(7.18)	3581.7	(7.18)	3767.2	(7.48)
CO mg/Nm³ (g/hp-h)	190.4	(0.37)	190.4	(0.37)	354.9	(0.67)
HC mg/Nm³ (g/hp-h)	20.4	(0.05)	20.4	(0.05)	18.5	(0.05)
PM mg/Nm³ (g/hp-h)	7.0	(0.02)	7.0	(0.02)	8.1	(0.02)
Emissions (Potential Site Variation)						
NOx mg/Nm³ (g/hp-h)	4298.0	(8.62)	4298.0	(8.62)	4520.6	(8.98)
CO mg/Nm³ (g/hp-h)	342.8	(0.67)	342.8	(0.67)	638.9	(1.20)
HC mg/Nm³ (g/hp-h)	27.2	(0.06)	27.2	(0.06)	24.6	(0.06)
PM mg/Nm³ (g/hp-h)	9.9	(0.02)	9.9	(0.02)	11.3	(0.03)

Figure – Generator Data Sheets – ML5

7.1.4 ML8 Generators

Generator set data sheet

Model:	C3500 D5
Frequency:	50 Hz
Fuel type:	Diesel
kVA rating:	3500 Standby 3125 Prime 2750 Continuous
Emissions level:	Unregulated

Fuel consumption	Standby kVA (kW)				Prime kVA (kW)				Continuous kVA (kW)			
Ratings	3500 (2800)				3125 (2500)				2750 (2200)			
Ratings without fan[1]	3594 (2875)				3220 (2576)				2845 (2276)			
Load	1/4	1/2	3/4	Full	1/4	1/2	3/4	Full	1/4	1/2	3/4	Full
US gph	51	91	133	177	47	83	120	161	42	75	107	141
L/hr	192	345	503	671	176	315	453	608	161	284	404	535

[1] Ratings for reference with the optional remote radiator cooling configuration. See note 1 under "Alternator data" section.

Engine	Standby rating	Prime rating	Continuous rating
Engine model	QSK95-G4		
Configuration	Cast iron, vee, 16 cylinder		
Aspiration	Turbocharged and after-cooled		
Gross engine power output, kWm (bhp)	3026 (4058)	2716 (3642)	2406 (3226)
BMEP at set rated load, kPa (psi)	2545 (369)	2283 (331)	2021 (293)
Bore, mm (in)	190.0 (7.48)		
Stroke, mm (in)	210.1 (8.27)		
Rated speed, rpm	1500		
Piston speed, m/s (ft/min)	10.5 (2067)		
Compression ratio	15.5:1		
Lube oil capacity, L (qt)	647 (684)		
Overspeed limit, rpm	1725		
Regenerative power, kW	230		
Fuel flow			
Maximum fuel flow, L/hr (US gph)	1393 (368)		
Maximum fuel inlet restriction with clean filter, kPa (in Hg)	30.48 (9)		
Maximum fuel return line restriction kPa (in Hg)	33.8 (10)		
Maximum fuel inlet temperature, °C (°F)	71.1 (160)		
Maximum fuel outlet temperature, °C (°F)	92.2 (198)		
Air			
Combustion air, m³/min (scfm)	241 (8489)	229 (8063)	206 (7256)
Maximum air cleaner restriction with clean filter, mm H_2O (in H_2O)	457 (18)		
Alternator cooling air, m³/min (cfm)	240 (8476)		

Exhaust	Standby rating	Prime rating	Continuous rating
Exhaust flow at set rated load, m³/min (cfm)	552 (19470)	517 (18227)	463 (16335)
Exhaust temperature at set rated load, °C (°F)	404 (758)	394 (741)	389 (732)
Maximum back pressure, kPa (in H_2O)	7 (28)		

Set-mounted radiator cooling	High Ambient	High Ambient Compact
Ambient design, °C (°F)	45 (113)	50 (122)
Fan load, kW_m (HP)	78 (105)	130 (175)
Coolant capacity (with radiator), L (US gal)	1155 (305)	1238 (327)
Cooling system air flow, m³/min (scfm)	3135 (110700)	2352 (83054)
Maximum cooling air flow static restriction, kPa (in H_2O)	0.12 (0.5)	0.12 (0.5)

Set-mounted radiator cooling	Enhanced High Ambient
Ambient design, °C (°F)	55 (131)
Fan load, kW_m (HP)	78 (105)
Coolant capacity (with radiator), L (US gal)	1155 (305)
Cooling system air flow, m³/min (scfm)	3135 (110700)
Maximum cooling air flow static restriction, kPa (in H_2O)	0.12 (0.5)

Optional remote radiator cooling			
Engine coolant capacity, L (US gal)	379 (100)		
Max flow rate at max friction head, jacket water circuit, L/min (US gal/min)	2419 (639)		
Max flow rate at max friction head, aftercooler circuit, L/min (US gal/min)	579 (153)		
Heat rejected, jacket water circuit, MJ/min (Btu/min)	78.4 (74260)	71.5 (67743)	64.4 (60986)
Heat rejected, aftercooler circuit, MJ/min (Btu/min)	18.8 (17795)	16.6 (15680)	13.1 (12336)
Heat rejected, fuel circuit, MJ/min (Btu/min)	0.33 (309)	0.33 (309)	0.33 (309)
Total heat radiated to room, MJ/min (Btu/min)	23.0 (21712)	20.7 (19591)	18.2 (17224)
Maximum friction head, jacket water circuit, kPa (psi)	59 (8.5)		
Maximum friction head, aftercooler circuit, kPa (psi)	59 (8.5)		
Maximum static head above engine crank centerline, jacket water circuit, m (ft)	18 (60)		
Maximum static head above engine crank centerline, aftercooler circuit, m (ft)	18 (60)		
Maximum jacket water outlet temp, °C (°F)	110 (220)	100 (212)	100 (212)
Maximum aftercooler inlet temp, °C (°F)	71.1 (160)	68 (155)	68 (155)
Maximum aftercooler inlet temp at 25 °C (77 °F) ambient, °C (°F)	46.1 (115)		

Note: For non-standard remote installations contact your local Cummins representative.

Weights[2]	
Unit dry weight kgs (lbs)	29529 (65100)
Unit wet weight kgs (lbs)	31194 (68771)

Note: Weights represent a set with standard features and alternator frame P80X. See outline drawing for weights of other configurations.

Figure – Generator Data Sheets – ML8

7.1.5 Generators ML6, 9, 10 and 11

December 7th, 2023

To Whom It May Concern:

With regards to Cummins Power Systems (CPS) manufactured diesel generator set model C3500 D5 rated for 50 Hz operation and equipped with Cummins QSK95-G4 engine:

When tested under the following conditions:

Table 1	
Fuel Specification:	ASTM D975 No. 2-D S15 diesel fuel with 0.0015% sulfur content (by weight), and 42-48 cetane number.
Air Inlet Temperature:	77 °F (25 °C)
Fuel Inlet Temperature:	104 °F (40 °C) at fuel pump inlet
Barometric Pressure:	29.53 in. Hg
Humidity:	NOx measurement corrected to 75 grains H2O/lb. dry air

Based on engine emissions validation testing, the table below represents the nominal performance and exhaust emissions data for the generator set listed above:

	Standby				
PERFORMANCE DATA	10%	25%	50%	75%	100%
Electrical Power (kWe)	280	700	1400	2100	2800
Engine Power (BHP at 1500 RPM/50Hz)	563	1146	2117	3087	4058
Fuel Consumption (L/Hr)	124	212	359	510	671
Exhaust Gas Flow (m3/min)	153	215	326	444	551
Exhaust Gas Temperature (°C)	276	356	383	388	403
Oxygen Dry (%)	15.2	12.9	11.4	11.1	10.4
NOx (Oxides of Nitrogen)	2785	4034	4646	3933	3959
NMHC (Nonmethane Hydrocarbons)	155	97	59	41	31
CO (Carbon Monoxide)	289	208	173	77	49
PM (Particulate Matter)	18	20	8	4	2
All emissions values above are cited as mg/Nm3@5% O2, 0°C and 101.325 kPa					
NOx (Oxides of Nitrogen)	1044	1513	1742	1475	1485
NMHC (Nonmethane Hydrocarbons)	58	36	22	15	12
CO (Carbon Monoxide)	108	78	65	29	18
PM (Particulate Matter)	7	8	3	2	1
All emissions values above are cited as mg/Nm3@15% O2, 0°C and 101.325 kPa					

Steady-State emissions recorded per ISO8178-1 during operation at rated engine speed (+/-2%) and stated constant load (+/-2%) with engine temperatures, pressures and emission rates stabilized.

Figure – Generator Data Sheets – ML5

The thermal power and flowrate of the gensets of ML6, 9, 10 and 11 used for the simulation are the same than ML7 and ML8 (all of those gensets are 2800kWe gensets). This assumption has been validated with the client.

7.1.6 ML7 Generators

Engine data

	Genset	Marine	O & G	Rail	C & I
Application	X				
Engine model	20V4000G94F				
Application Group	3D				
Legislative body	Fuel-consumption optimized				
Test cycle	D2				
Fuel sulphur content [ppm]	5				
mg/mN³ values base on residual oxygen value of [%]	15				

Engine raw emissions*

Cycle point	[-]	n1	n2	n3	n4	n5
Power	kW	3090	2315	1543	772	309
Power relative	[-]	1	0.75	0.5	0.25	0.1
Engine speed	1/min	1501	1499	1499	1499	1499
Engine speed relative	[-]	1	1	1	1	1
Filter smoke number	Bosch	0.11	0.2	0.38	0.48	0.09
Exhaust temperature after ETC	grdC	455.1	445.1	444.5	396.8	268.2
Exhaust back pressure after ETC (total)	mbar	29	14	7	0	-4
NOX-Emissions specific	g/kWh	7.81	9.55	7.91	6.13	9.41
SO2-Emissions specific	g/kWh	0.002	0.002	0.002	0.002	0.003
CO-Emissions specific	g/kWh	0.27	0.33	0.42	0.68	1.82
HC1-Emissions specific	g/kWh	0.06	0.06	0.09	0.17	0.54
CO2-Emissions specific	g/kWh	622.4	602.8	629.5	698.4	852
PM-Emissions specific (Meas.)	g/kWh	0.017	0.023	0.054	0.095	0.06
NOX-Emissions (based on 15% O2)	mg/m3N	1074	1357	1075	757	932
CO2-Emissions (based on 15% O2)	mg/m3N	83834	83784	84008	83847	82686

Figure – Generator Data Sheets – ML7

The thermal power was estimated using the ratio between the electrical power of ML7 gensets (2315 kW_e) and the reference ML8 gensets (2800 kW_e and 2000 kW_{th}):

$$P_{th} = \frac{2315}{2800} \times 2000$$

$$P_{th} = 1654\ kW$$

7.2. Other campus buildings data set (Data4, Vantage and Microsoft)

7.2.1 Chillers

For the buildings DC01, DC02, DC03, DC07, DC08 and DC09:

- The same chiller characteristics as those used for ML5 were adopted because the chillers installed on the building have similar dimensions (approximately 9 m long).

For the buildings DC11, DC12, DC14, and DC15, two categories of chillers were identified based on their dimensions :

- The large chillers (approximately 13 m long) were assumed to have the same characteristics as the chillers used for ML7, ML8, ML9, ML10, and ML11, since they have comparable dimensions.
- The smaller chillers (approximately 9 m long) were assumed to have the same characteristics as the ML5 chillers for the same reason.

For the buildings DC04, DC05, DC06, and DC10:

- The chillers identified on these buildings are approximately half the size of the 9 m chillers used at Equinix ML5. Therefore, their cooling power and flow rate were estimated by applying a 50% scaling factor relative to the ML5 chiller characteristics.

For Vantage MXP2:

- The same chiller characteristics as those used for ML7 and ML8 were adopted because the chillers installed on the building have similar dimensions (approximately 13 m long).

For Microsoft MIL03:

- The same chillers as those used for ML7 and ML8 were selected, as the projects are of a similar order of magnitude in terms of building size, number of generators, and overall power capacity.
- The number of chillers for MIL03 was determined based on the ratio between the number of gensets installed in MIL03 (8 gensets) and the number installed in ML8 (12 gensets). Applying this ratio to the ML8 configuration of 18 chillers results in a total of 12 chillers for the Microsoft building.

7.2.2 Generators

For the estimation of thermal power rejected by the gensets in the different campuses, a scaling methodology was applied based on reference data from Equinix sites.

The approach consists of using the known relationship between electrical power input and thermal heat rejection for gensets where both values were available (Equinix). This ratio was then applied to other sites where only the electrical power of the gensets was known, in order to estimate their corresponding thermal power output.

The scaling principle is as follows:

For Data4:

The thermal power was estimated using the ratio between the electrical power of Data4 gensets and the reference Equinix gensets:

$$P_{th} = \frac{3200}{2800} \times 2000$$

$$P_{th} = 2285\ kW$$

For Microsoft (MIL03):

The same methodology was applied using the corresponding electrical power ratio:

$$P_{th} = \frac{3000}{2800} \times 2000$$

$$P_{th} = 2143\ kW$$

For Vantage (MXP2):

No scaling was required, as the thermal power values were already provided directly in the technical datasheet.

$$P_{th} = 2756\ kW$$

Overall, this method ensures consistency by leveraging validated Equinix reference performance data and applying proportional scaling based on electrical power when direct thermal rejection values were not available.

The technical datasheets used for this calculation are illustrated below.

GENSET POWER WITHOUT FAN	PERCENT LOAD	ENGINE POWER	OVERALL SOUND	100 HZ	125 HZ	160 HZ	200 HZ	250 HZ	315 HZ	400 HZ	500 HZ	630 HZ	800 HZ
EKW	%	BKW	dB(A)	dB(A)	dB(A)	dB(A)	dB(A)	dB(A)	dB(A)	dB(A)	dB(A)	dB(A)	dB(A)
3,200.0	100	3,368	126.2	90.3	99.0	97.9	103.3	102.1	110.4	110.0	111.6	112.1	113.7
2,880.0	90	3,032	126.3	90.0	99.1	97.8	102.9	102.1	109.9	109.6	111.2	111.9	113.4
2,560.0	80	2,695	125.3	89.6	97.9	97.5	102.1	102.1	109.2	109.2	110.9	111.8	112.9
2,400.0	75	2,526	124.8	89.5	97.4	97.4	101.8	102.4	109.1	109.4	110.9	111.9	112.8
2,240.0	70	2,358	124.4	89.4	96.5	97.3	101.5	102.5	108.6	109.8	110.8	111.9	112.6
1,920.0	60	2,021	123.9	89.0	96.4	97.5	101.4	102.7	107.7	110.0	110.5	111.8	112.2
1,600.0	50	1,684	123.2	88.0	96.6	97.8	100.7	102.3	107.3	109.4	110.2	111.6	111.9
1,280.0	40	1,347	122.3	87.1	97.0	99.1	100.0	102.5	106.6	108.9	110.0	111.0	110.6
960.0	30	1,011	121.8	86.1	96.1	99.4	99.1	102.9	106.3	108.8	110.4	111.4	109.9
800.0	25	842	121.7	85.6	94.9	98.8	98.4	103.2	106.5	108.9	110.9	112.1	110.0
640.0	20	674	121.9	85.0	94.0	97.9	97.4	103.0	106.6	109.3	111.7	113.0	111.0
320.0	10	337	121.9	84.9	94.3	98.5	94.4	102.3	105.9	109.0	111.4	113.4	111.5

Figure – Data Sheet – Generator Sets Data4 – 3200 kWe

Package Performance

Performance	Standby		Mission Critical		Prime	
Engine Speed	1500 rpm		1500 rpm		1500 rpm	
Frequency	50 Hz		50 Hz		50 Hz	
Gen set power rating with fan	2600 ekW		2600 ekW		2360 ekW	
Gen set power rating with fan @ 0,8 power factor	3250 kVA		3250 kVA		2950 kVA	
Emissions	< 2000 mg NOx		< 2000 mg NOx		< 2000 mg NOx	
Performance number	EM4789-01		EM4793-01		EM4797-01	
Fuel Consumption						
Per il valore di consumo di combustibile fare riferimento al valore riportato nella tabella di pag. 11 (tipologia generatori con valvola elettrica)						
Cooling System						
Radiator air flow restriction (system) – kPa (in. water)	0,12	(0,48)	0,12	(0,48)	0,12	(0,48)
Radiator air flow – m³/min (cfm)	2878	(101635)	2878	(101635)	2878	(101635)
Engine coolant capacity – L (gal)	179,0	(47,3)	179,0	(47,3)	179,0	(47,3)
Radiator coolant capacity – L (gal)	202,0	(53,4)	202,0	(53,4)	202,0	(53,4)
Total coolant capacity – L (gal)	381,0	(100,7)	381,0	(100,7)	381,0	(100,7)
Inlet Air						
Combustion air inlet flow rate – m³/min (cfm)	222,8	(7867,2)	222,8	(7867,2)	208,6	(7364,7)
Exhaust System						
Exhaust stack gas temperature – °C (°F)	492,2	(917,9)	492,2	(917,9)	491,2	(916,2)
Exhaust gas flow rate – m³/min (cfm)	598,6	(21138,7)	598,6	(21138,7)	554,6	(19582,0)
Exhaust system backpressure (maximum allowable) – kPa (in. water)	7,0	(28,1)	7,0	(28,1)	7,0	(28,1)
Heat Rejection						
Heat rejection to jacket water – kW (Btu/min)	893	(50811)	893	(50811)	821	(46693)
Heat rejection to exhaust (total) – kW (Btu/min)	2756	(156710)	2756	(156710)	2555	(145286)
Heat rejection to aftercooler – kW (Btu/min)	905	(51446)	905	(51446)	773	(43964)
Heat rejection to atmosphere from engine – kW (Btu/min)	168	(9567)	168	(9567)	163	(9254)
Heat rejection from alternator – kW (Btu/min)	113	(6426)	113	(6426)	88	(5010)

Figure – Data Sheet – Generator Sets Vantage – 2600 kWe

Tabella 5-2: Principali caratteristiche dei gruppi elettrogeni di back-up a servizio dell'impianto

Impianto	Punto di emissione	Potenza elettrica (kWe)	Potenza termica (kWt)
Generatore M1	E1	3.000	7.475
Generatore M2	E2	3.000	7.475
Generatore M3	E3	3.000	7.475
Generatore M4	E4	3.000	7.475
Generatore M5	E5	3.000	7.475
Generatore M6	E6	3.000	7.475
Generatore M7	E7	3.000	7.475
Generatore M8	E8	3.000	7.475
Generatore M9	E9	1.120	3.000
Generatore M10	E10	140	414

Figure – Data Sheet – Generator Sets Microsoft – 3000 kWe